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LAND AND HOLD SHORT OPERATIONS RISK ASSESSMENT

FINAL

Office of the Assistant Administrator
For System Safety

System Safety Engineering and Analysis Division, ASY-300

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GLOSSARY

ALD	Available Landing Distance
ALPA	Air Line Pilots Association
AOPA	Aircraft Owners and Pilots Association
ASRS	Aviation Safety Reporting System
ATA	Air Transport Association
ATCT	Airport Traffic Control Tower
ATIS	Automatic Terminal Information Service
CRDA	Converging Runway Display Aid
ERC	LAHSO Event Review Committee
FAA-AAI	FAA Office of Accident Investigation
FAA-AAS	FAA Office of Airport Safety and Standards
FAA-AIDS	FAA Accident Incident Database System
FAA-AFS	FAA Flight Standards Service
FAA-ARP	FAA Associate Administrator for Airports
FAA-ASC	FAA Office of System Capacity
FAA-ASY	FAA Office of System Safety
FAA-ATO	FAA Air Traffic Operations Program
HSO	Hold Short Overrun (passing the hold short point without clearance)
LAHSO	Land And Hold Short Operation
NAIMS	National Airspace Incident Monitoring System
NATA	National Air Transport Association
NATCA	National Air Traffic Controllers Association

NBAA	National Business Aviation Association
PHA	Preliminary Hazard Assessment
PHL	Preliminary Hazard List
RAA	Regional Airline Association
SOIA	Simultaneous Offset Instrument Approaches
SOIR	Simultaneous Operations on Intersecting Runways
SWA	Southwest Airlines
SWAPA	Southwest Airlines Pilots Association

Executive Summary

In the spring of 1999, the FAA Office of System Safety led a government-industry group to conduct a safety risk assessment of land and hold short operations (LAHSO). The objective of this analysis was to answer the following questions:

- *What are the hazards associated with LAHSO?*
- *Given the hazards and controls, what are the residual risks associated with LAHSO?*
- *How can residual risks be reduced?*

This assessment does not judge the acceptability of LAHSO risks. The intent is to provide information concerning risks based on analyses of statistical data and the input of subject matter experts who are familiar with and/or have participated in the procedure.

What are the hazards? Statistical information and expert judgment indicate that the most critical LAHSO hazards are associated with:

- Runway conditions (e.g., wet or contaminated runways),
- Controller-pilot communications (e.g., communications errors which cause confusion as to whether a hold short clearance is in effect),
- Piloting technique (e.g., the ability of the pilot to recognize the hold short point, or to compensate for environmental or other conditions such as tailwinds or crosswinds), and
- Rejected landings (e.g., the risk of collisions or single aircraft accidents caused by evasive maneuvering).

What are the residual risks associated with LAHSO? There are three general types of LAHSO controls: Type 1) restrict the application of LAHSO, Type 2) reduce the probability that the LAHSO aircraft does not stop before the hold short point, and Type 3) reduce the probability of a collision given that the LAHSO aircraft does not stop before the hold short point. Most existing controls are of the second type; addressing the likelihood of stopping before the hold short point (for example, by increasing the conspicuity of the hold short point or lengthening the available landing distance). Reducing the probability of a hold short overrun or rejected landing to zero is problematic for several reasons:

- It is difficult to eliminate human error (e.g., the probability that the LAHSO aircraft incorrectly accepts a full-length clearance intended for another aircraft).

- It is difficult to eliminate all exogenous variables (e.g., the probability of wildlife or debris on the runway which causes a rejected landing).

- The possibility of increased future exposure to hazardous conditions.

Thus, the key issues for decisionmakers are: 1) Do existing controls adequately limit the probability that the LAHSO aircraft does not stop before the hold short point? 2) If not, is the risk of a collision, given that the LAHSO aircraft does not stop before the hold short point, acceptable?

How can residual risks be reduced? This analysis suggests five broad strategies to further reduce LAHSO risks:

- ***Approval of LAHSO at specific airports***. The FAA should consider applying more rigorous approval criteria that would restrict LAHSO only to those airports where there is a significant and demonstrated economic/capacity need.

- ***Hazard tracking and monitoring***. The FAA should establish a hazard tracking and monitoring process to assess the effectiveness of current and future controls This process should include: 1) risk assessments to be performed at specific sites (e.g., based on frequency of LAHSO operations, accident/incident or event reports, etc.), 2) tracking and monitoring of event reports, and 3) periodic system-wide collection of LAHSO activity data.

- ***Application of safety risk management principles***. All revisions to the existing system of LAHSO controls and all waivers to existing restrictions and regulations should be subjected to a safety risk management (SRM) process (e.g., as described in FAA Order 8040.4).

- ***Additional controls to limit the probability of a hold short overrun or rejected landing*****.** See text.

- ***Additional controls to limit the probability of a collision given a hold short overrun or rejected landing*****.** Given a hold short overrun or rejected landing, the current system depends, in part, on human responses for recovery; namely, controller intervention, and flight crew see-and-avoid procedures. In addition, the FAA and industry are currently developing rejected landing procedures for specific airports/runways. This assessment offers several suggestions to further minimize the probability of a collision given an overrun or rejected landing—for example, aircraft sequencing—and also identifies several hazards which may impair current recovery procedures.

Summary of Findings

Policy Issues and Options. The probability of a LAHSO-related collision depends on: 1) R_L, the frequency or rate of LAHSO use, 2) P_{HSO}, the likelihood of a hold short overrun, and 3) P_{COL}, the probability that two airplanes are in the intersection at the same time given a hold short overrun. The FAA, then, has three general means to control LAHSO-risks:

- Restrict the application of LAHSO,
- Adopt controls that reduce the likelihood of a hold short overrun or rejected landing, or
- Adopt controls that reduce the likelihood of collisions given a hold short overrun or rejected landing.

Restrict the application of LAHSO. Current regulations require that a facility "determine that a valid operational need exists before conducting simultaneous takeoff and landing or simultaneous landing operations." This need may be based on factors such as airport capacity/acceptance rates, arrival/departure delays, and fuel consumption (FAA Order 7210.3P). It is not clear, however, that a consistent national policy is being applied to this process. Survey data collected by the FAA Air Traffic Operations Program (FAA-ATO), for example, show that LAHSO constitutes less than one percent of total operations at some facilities.

Regulatory and equipage requirements create economic disincentives for LAHSO at locations where the regulatory costs exceed expected benefits. In addition, FAA Notice 7110.199 limits air carrier LAHSO to specific airports (listed in 7110.199 Appendices I and II). However, given the inherent incremental risks associated with LAHSO (see Section IV), the FAA should consider applying more rigorous approval criteria that would restrict LAHSO only to those airports where there is a significant and demonstrated economic/capacity need.

Reduce the likelihood of hold short overruns/rejected landings. Most existing requirements control LAHSO risks by targeting the factors that may cause hold short overruns; for example, limitations on tailwinds and wet runways. In some cases, these controls may transfer risks; lessening the probability of a ground collision, but potentially increasing the probability of an airborne accident. A key question, then, is whether existing control measures reduce accident risks to an acceptable degree.

Reduce the likelihood of collisions given a hold short overrun. If the probability that the pilot cannot stop before the hold short point is unacceptably high, then additional controls must be applied to reduce the likelihood of a collision given the hold short overrun (e.g. traffic sequencing or spacing). In fact, some policies, either currently in effect (e.g., LAHSO-night) or under consideration (e.g., LAHSO-wet), may increase the conditional probability of a collision given a hold short overrun in that they may reduce the likelihood that intersecting traffic will be able to "see-and-avoid."

Baseline Estimates of LAHSO Risks. The Office of System Safety (FAA-ASY) constructed estimates of the number of land and hold short operations, the number of hold short overruns, and the number of pilot initiated go-arounds, using survey data from FAA-ATO and incident statistics derived from more than 120 Aviation Safety Reporting System (ASRS) and National Airspace Incident Monitoring System (NAIMS) reports. *For reasons discussed in Section IV, these estimates may not accurately represent LAHSO risks and are used primarily to compare with expert judgment*.

- The historical rate of LAHSO hold short overruns plus pilot initiated go-arounds is estimated at about 4.1 per million operations. In comparison, runway incursions occur at a rate of approximately 4.5 per million operations. (See Section IV for a full discussion.)

- The data indicate that a failure to stop before the hold short point (leading to a hold short overrun or go-around) is usually the result of one of three factors: 1) controller-pilot communications error, 2) piloting technique (including the pilot's ability to adequately compensate for wind conditions), and 3) exogenous factors (e.g. preceding traffic on the runway, mechanical failure). These factors are largely independent (for example, of the 33 hold short overrun events reported between 1994-1998, only 3 involved both a piloting error and a communications problem). Communications errors and piloting technique are the leading factors contributing to the failure to stop before the hold short point.

- These historical rates may understate present and future risks because: 1) the use of LAHSO may increase in the future, 2) historical statistics may understate risks, 3) future LAHSO may experience increased exposure to potentially hazardous conditions, and 4) current controls may transfer risks.

Future use of LAHSO. All other things being equal, the annual probability of a LAHSO accident depends on the number of LAHSO performed. According to the *FAA Aerospace Forecast, Fiscal Years 1999-2010*, total operations at FAA and contract Airport Traffic Control Towers (ATCT) increased by approximately 0.5% per year between 1990 and 1998. But, projected growth for the next twelve years is expected to average nearly 2% per year; an increase of nearly 16 million operations by 2010. If the number of LAHSO grows proportionally to total operations (and assuming that about 2.7 million LAHSO are performed annually at present) the expected number of LAHSO in 2010 would be approximately 3.2 million.

This estimate may be low, however. In areas where the system is already constrained by available runways, increased traffic would require runway construction and/or measures that would increase the utilization of existing runways. Although LAHSO is not the only means to increase capacity given a fixed supply of runways, it is plausible that, in the absence of additional restrictions, LAHSO will also be used to increase acceptance rates at physically constrained facilities.

Probability of a hold short overrun or rejected landing. FAA-ASY estimates that the historical rate of hold short overruns and pilot initiated go-arounds is approximately 4.1 per million land and hold short operations. All other things equal, the overrun/go-around rate must decline even faster than the growth rate of LAHSO in order for annualized collision risks to be reduced.

It is important to note that cases where pilots reported that they declined a land and hold short clearance, but traffic nonetheless crossed their runway, are not included in the hold short overrun count. This suggests that errors are more frequent than the hold short overrun data alone imply.

Also, evidence suggests that ASRS and NAIMS data do not give a complete count of all events. As one participant suggested, "no harm, no foul;" thus an event may not be reported in any voluntary or mandatory system. In other words, reporting rates are less when there is little or no perceived consequence. Hence, the hold short overrun and go-around counts presented here are likely to be lower bounds. (See recommendation regarding hazard tracking in Section X.)

Probability of a collision given a hold short overrun or rejected landing. Changes in LAHSO policy could increase collision risks even if the hold short overrun rate is unchanged or declines. For example, in approximately one-third of ASRS/NAIMS LAHSO reports, one or both aircraft crews reported having to make an evasive maneuver to avoid a perceived collision threat. It should be emphasized that the risk of a midair collision after a rejected landing by a LAHSO aircraft represents a potentially greater hazard than aircraft colliding on the ground after a hold short overrun. Changes to policies regarding night or wet-runway LAHSO could affect aircraft conspicuity and, therefore, the effectiveness of see-and-avoid procedures. Moreover, some members of the team expressed concerns that as LAHSO rates rise, the likelihood of a collision given a hold short overrun may rise due to closer sequencing of intersecting traffic.

Risk transfer. Another consideration is that some LAHSO controls represent a transfer of risks. For example, new FAA-Flight Standards guidelines may increase the likelihood of a rejected landing if a specified touchdown zone cannot be attained. While this may reduce the risks associated with a hold short overrun, it may increase risks associated with a rejected landing.

Suggested Risk Reduction Strategies. Based on its analysis of the statistical evidence and input from FAA and industry representatives, FAA-ASY offers the following risk reduction strategies regarding land and hold short operations:

Approval of LAHSO at specific airports. The FAA should consider applying more rigorous approval criteria that would restrict LAHSO only to those airports where there is a significant demonstrated economic/capacity need.

Hazard tracking and monitoring. FAA should establish a hazard tracking and monitoring process to assess the effectiveness of current and future controls (for example, this function could be an extension of the current Event Review Committee). This process should include:

- Risk assessments to be performed at specific sites (e.g., based on frequency of LAHSO operations, accident/incident or event reports, etc.). The Office of System Safety could assist in coordinating this effort.

- Tracking and monitoring of event reports.

- Periodic system-wide collection of LAHSO activity data. Surveys would be done periodically (with surveys "seasonally adjusted" to permit year-to-year comparisons), to record:
  - The number of LAHSO clearances
  - Types of operations involved (both "active" and "passive")
  - Types of aircraft involved
  - Controller and pilot concerns regarding the procedure.

Application of Safety Risk Management Principles. All revisions to the existing system of LAHSO controls and all waivers to existing restrictions and regulations should be subjected to a safety risk management (SRM) process (e.g., as described in FAA Order 8040.4). For example, in the case of waivers to specific regulations, SRM should be used to develop a process and criteria by which applications for waivers would be evaluated. This would increase the likelihood that a consistent safety policy was applied to all waiver petitions.

Joint government/industry education program for general aviation. The FAA and industry should launch an education and awareness program. This program would also develop and distribute accurate, non-technical and readable materials related to LAHSO safety.

Issuing Hold Short or Turn-Off Instructions After Landing. Several participants raised a concern that LAHSO restrictions may be circumvented by issuing hold short instructions after landing. In many cases, these instructions pose no safety issue. However, in some cases such instructions may increase risks since many LAHSO controls would no longer apply even though LAHSO-like risks may apply. Suggested risk reduction strategies:

- Education/training and policy guidance material for air traffic controllers and pilots to remind them that hold short instructions after landing should not be used as a way to circumvent LAHSO controls (e.g., permitting LAHSO-like operations on wet runways).

- Education/training and policy guidance to pilots to remind them that hold short/turn-off instructions should not be accepted (i.e., the default is "unable") unless the pilot can see the hold short point or taxiway, and is capable of stopping and/or exiting at that point. This decision should take into consideration runway conditions.

- Intersecting traffic should be notified of traffic holding short.

Accident Risks Associated with LAHSO Communications Errors. The FAA-industry team considered three types of accident scenarios related to communications errors: 1) hold short overrun and collision resulting from miscommunication between air traffic control and the LAHSO aircraft, 2) single aircraft accident involving evasive maneuvering by the full-length aircraft as a result of miscommunication between air traffic control and the full-length aircraft, and 3) collision as a result of an incursion by the full-length aircraft onto the LAHSO runway as a result of miscommunication between air traffic control and the full-length aircraft. Communications problems are a significant source of LAHSO risks; appearing in more ASRS/NAIMS reports than any other factor. Thirty-four percent of LAHSO hold short overruns involve controller-pilot miscommunication. Suggested risk reduction strategies:

- *Improved cooordination between approach and tower*. FAA-Flight Standards Information Bulletins require that the pilot advise, upon initial contact, if a LAHSO clearance cannot be accepted. ASRS data, however, indicate that this information is not always coordinated between approach and tower. The FAA should establish procedures whereby this information is coordinated between approach and local controllers.

- *Foreign air carrier participation in land and hold short operations.* While the risk assessment team did not have the opportunity to fully analyze the possible safety implications of foreign air carrier participation in LAHSO (since, at the time of the risk assessment working sessions, the understanding was that such operations were prohibited), it did identify foreign carrier operations as a potential hazard with respect to communications. Recently issued Flight Standards guidance material, however, lays out criteria for such operations.

  The FAA should develop risk-based standards for evaluating and approving foreign air carriers for participation in LAHSO before permitting such operations as a National Policy. Issues that should be considered include (also see Section IX):

  - The accident/incident history of the carrier (e.g., with respect to piloting or crew coordination issues).
  - Possible miscommunication (using emergency or non-standard phraseology) between foreign pilots and ATC during a rejected landing.
  - Possible effects of lack of airport familiarity on LAHSO accident/incident likelihoods.
  - Possible effects of lack of LAHSO procedure familiarity on hold short overrun or rejected landing likelihoods.
  - Possible effects of LAHSO lighting configuration on foreign crew not familiar with the U.S. configuration including possible safety issues concerning differing LAHSO lighting standards between countries. Variability of English skills within a given foreign carrier.

- *Anti-stuck microphone and anti-block radio technology*. Require the use of anti-stuck microphone and anti-blocking radio technology for air traffic equipment and radio equipment in aircraft operating at ATCT where LAHSO are permitted.

- *Site-specific studies of radio interference.* Site-specific studies of radio interference should be included as part of the site-specific risk assessments and on-going hazard tracking programs (see Section X).

- *Pilot training: "passive" LAHSO*. LAHSO training should not be limited to operators conducting LAHSO. Pilot training material should include information on the criticality of communications errors during LAHSO. This material should address hazards associated with communications errors involving the full-length (i.e., non-LAHSO) aircraft, and emphasize the need for the intersecting aircraft to acknowledge the notification of intersecting traffic holding short.

- *Long-term: Non-voice communications*. The FAA should investigate the application of non-voice technologies for exchanging information between controllers and flight crews (e.g., datalink) during a land and hold short operation.

- *Long-term: Automated LAHSO light system*. The FAA should investigate the feasibility of an automated system of LAHSO lights to give positive visual confirmation of a hold short clearance. *However, the FAA should not commit to the implementation of an automated LAHSO light system until a Preliminary Hazard Assessment (PHA) of the system concept is completed (see Section VII).*

Risks Associated with Piloting Technique. The FAA-industry team considered two broad types of pilot error scenarios: 1) accidents as a result of a failure to correctly recognize the hold short point, and 2) accidents as a result of landing technique. Crew performance is an important factor in most accidents and the LAHSO event history and team ratings are consistent with this generalization. Most risk assessment team participants concluded that the current FAA configuration (a single pulsing bar at the hold short point) is an acceptable control against the hazard that the pilot is unable to identify the hold short point.

Two participants stated that the fact that the lights were not controlled is a hazard. One of these participants felt that uncontrolled lights should not be used (and, therefore, that in the near-term LAHSO-night be prohibited). Several participants expressed reservations over the net benefits of any two bar system. Significantly, none of the participating pilots' groups rated the uncontrolled two-bar configuration superior to the uncontrolled single-bar configuration.

One participant suggested incorporating LAHSO restrictions into 14 CFR §121.438, i.e. prohibit a second-in-command with less than 100 hours in type from performing a LAHSO unless with a qualified check pilot. The available statistical evidence does indicate a relationship between experience and the likelihood of an overrun.

The lack of testing and analysis of the possible deleterious effects of a two-bar system causes concerns in view of the analysis of ASRS/NAIMS go-around events presented in Section III:

approximately 12 percent of LAHSO aircraft go-arounds involved a conflict with an aircraft that was delayed in departing the runway (this hazard is discussed in greater detail below). The visual information provided by FAA-AAS does raise a concern that the two-bar system could exacerbate this problem and result in increased collision risks with intersecting traffic.

Suggested risk reduction strategies:

- *Implementation of the uncontrolled two-bar system should commence only after thorough testing and evaluation to determine: 1) the net benefits of the alternative system, and 2) the possible disbenefits including runway exiting delays and effects on intersecting traffic.*

- *All changes to existing LAHSO controls, including alternative LAHSO light configurations, should be evaluated in accordance with the requirements of FAA Order 8040.4, Safety Risk Management.* The FAA should not commit to an automated two-bar system until a thorough Preliminary Hazard Assessment (PHA), that includes simulation testing, is completed. Issues include:

  - Are there potential hazards associated with lights that come on or off for an operation on an intersecting runway?
  - For a condition where the LAHSO aircraft is followed by a full-length arrival on the same runway, when are the lights turned off? Before the LAHSO aircraft is cleared to cross a hold short runway? After?
  - For a condition where a full-length arrival is followed by a LAHSO arrival on the same runway, when are the lights turned on? While the first aircraft is still on the runway? After it has cleared?
  - Will the lights be automatically turned on? Automatically turned off?
  - Will the algorithm that governs on/off states be the same for all airports? Are there airport or runway configuration specific issues that will require different algorithms for different sites?
  - Will the on/off algorithm require that the system know the position of all aircraft?
  - If algorithms are different for different airports. Could the conditions under which the lights are turned on or off be different for different airports? Is this a hazard?
  - Could there be different algorithms for different runway combinations at the same airport? Is this a hazard?

- *Foreign air carrier participation in land and hold short operations.* . The FAA should develop risk-based standards for evaluating and approving foreign air carriers for participation in land and hold short operations.

- *Minimize the likelihood of go-arounds as a result of declined LAHSO clearances.* A critical hazard control in the LAHSO procedure is the pilot's knowledge of her/his aircraft state, personal condition, and comfort with a hold short operation. Team discussions and ASRS data, however, indicate that under some conditions pilots perceive that an "unable" response to a LAHSO clearance will result in a "punitive" go-around. Whether or not they are punitive, ATC instructed go-arounds reduce the effectiveness of existing controls in that they may induce some pilots to accept landing risks that they would not otherwise take. Two measures to reduce the likelihood of go-arounds are:

- Issue system-wide clarification of LAHSO policy regarding go-arounds issued after a rejected LAHSO clearance.
- Improve coordination between approach and local controllers to minimize the likelihood of go-arounds—particularly after approach has been notified that an arrival is unable to hold short.

- *Experience.* Accident and incident data suggest a link between pilot experience and the likelihood that the hold short point will be overrun. The FAA should evaluate the need for establishing LAHSO experience requirements, including: 1) flight hours, 2) flight hours in type, and 3) familiarity with airport/runway.

- *Windshear*. Establish a general termination provision to include "when windshear is anticipated" (e.g., when thunderstorms are in the area), rather than the current requirement which depends on pilot reports.

Risk Associated With Rejected Landings. Several team participants expressed concerns over the existing criteria used to determine when special rejected landing procedures are required. In addition, FAA-Flight Standards guidance material may increase the likelihood of rejected landings since such a procedure would become a "control" with respect to hold short overrun risks.

- *The FAA and Industry should continue to collaboratively develop rejected landing procedures.* This collaborative approach should consider:

  - The points from which the rejected landing is initiated.
  - Potential conflict with terrain or obstacles along the rejected landing flight path.
  - Potential conflicts with other procedural requirements, e.g., visibility requirements—does the procedure take a VFR flight into instrument meteorological conditions? Is there a possible conflict between a rejected landing procedure and a one-engine out procedure for the full-length aircraft?
  - Performance of the LAHSO aircraft and the full-length aircraft.
  - Consideration of different full-length traffic scenarios (e.g., arrival, departure, go-around).

  Investigation indicates that a variety of tools—e.g., simulation, computer modeling, etc.—are available and could assist in validating rejected landing procedures. For example, computer modeling has been used to study the capacity and safety implications of various SOIA (simultaneous offset instrument approach) procedures.

Hold Short Overrun and Collision Risks Associated with Wet Runways. The risk assessment considered two cases: 1) evaluation of risks assuming that wet runway operations are prohibited, 2) evaluation of risks assuming that wet runway operations are permitted in accordance with the February 9, 1999 agreement between the FAA, the Air Transport Association (ATA), and the Air Line Pilots Association (ALPA). The FAA-industry team did not make any recommendation to introduce additional controls assuming that wet runway land and hold short operations are prohibited. Some participants, however, expressed reservations over the ability of the airport and Air Traffic Control (ATC) to detect and communicate changes in runway conditions in a timely manner. Suggested risk reduction strategies:

- *Establish explicit inspection/communication policies*. The airport and air traffic should establish explicit procedures and responsibilities for ensuring timely detection and notification of wet runway conditions (for example, as part of a Letter of Agreement). Such provisions should ensure that the airport takes responsibility to inspect and notify air traffic of hazardous conditions without requiring that air traffic request a runway condition report. (See Section V for a full discussion.)

- *All changes to existing LAHSO controls, including conditions for LAHSO-wet, should be evaluated in accordance with the requirements of FAA Order 8040.4, Safety Risk Management*. Before developing policies for and approving LAHSO-wet, the FAA should conduct a risk assessment of wet runway land and hold short operations to include a thorough identification of hazards, analysis of accident likelihoods and severities, and an assessment of risks against acceptability criteria. (See Section V for a full discussion.) Hazards to be considered should include (but are not limited to):

  - Effects of water/precipitation on marking/signage conspicuity
  - Effects of water/precipitation on lighting conspicuity
  - Effects of water/precipitation on conspicuity of intersecting traffic
  - Possible synergistic effects of water/precipitation and night-time land and hold short operations
  - Effects of runway type/condition (e.g., treatment type, groove shape, groove spacing, depth, method used to construct grooves, volume of airplane traffic, frequency of evaluations and maintenance, etc.) and adequacy of current runway inspection/maintenance Advisory Circulars for application to LAHSO.
  - Aircraft systems (e.g., brake type, effects of wear on brake performance, anti-skid technology, etc.)

Hold Short Overrun and Collision Risks Associated with Contaminated Runways. Other than in the definition section, there is no explicit reference to contaminated runways in FAA Notice 7110.199. The Notice, however, instructs ATC to terminate LAHSO in the presence of hazardous conditions. The FAA-industry team did not recommend any additional controls regarding contaminated runways. Most participants agreed that, in the presence of a prohibition of LAHSO-wet, current controls, with respect to runway contamination, were acceptable. Suggested risk reduction strategies:

- *All changes to existing LAHSO controls, including conditions for LAHSO-wet, should be evaluated in accordance with the requirements of FAA Order 8040.4, Safety Risk Management (see suggested risk reduction strategies for LAHSO-wet above).* In addition to the discussion above, the risk assessment of LAHSO-wet should identify what, if any, hazards are associated with transitional wet-to-contaminated states, and whether controls will ensure timely detection and notification of such a condition.

LAHSO at night. Hold short overrun and rejected landing/go-around events in the ASRS/NAIMS data, NTSB accident data, and subjective risk ratings raise concerns over the adequacy of the LAHSO lights as a control for night LAHSO. Many, if not most, overrun and go-around events do not involve a failure of the LAHSO aircraft crew to recognize the hold short point. At the same time, the data show that the ability of pilots and controllers to see traffic may be a critical element of the LAHSO control set. While no member of the team made any recommendations to restrict or prohibit LAHSO at night, the Office of System Safety recommends that consideration of night/conspicuity issues be addressed in site-specific risk assessments.

Conclusion. LAHSO is one subset of a larger issue confronting the National Airspace System (NAS): how can capacity be safely increased given the economic, political, and physical constraints on existing airport runways? Good management practice dictates that investment in capital must be related to the value of the output that the capital is expected to produce. LAHSO, while not capital in a physical sense, is by most accounts a critical, capacity enhancing asset of the NAS. In this context, the risk reduction strategies suggested in this report can be seen, not simply as safety improvements, but as investments that will increase public confidence in and preserve this important asset.

Discussion of Team Comments to the Draft Report

A draft risk assessment was completed in June of 1999 and distributed to members of the risk assessment team for review and comment. Representatives from ALPA, AOPA, ATA, RAA, SWA, FAA-AFS, FAA-ARP, and FAA-ATS provided comments which are shown in their entirety in Appendix VII. Discussions of comments, grouped by category, are shown below.

A. General Comments, Comments on the Summary of Findings and Baseline Risk Estimates

1. ALPA

We think that (the draft 1999 LAHSO Risk Assessment) accurately identifies the risks associated with LAHSO and outlines sound management strategies for risk reduction. As we have previously stated, we believe that LAHSO is a viable capacity enhancement tool. Application of these risk reduction strategies will improve the safety of the operations.

2. AOPA

The suggestion to limit Land and Hold Short Operations (LAHSO) to select locations where there is a demonstrated economic/capacity need defeats the purpose of the original intent of the LAHSO program. LAHSO under its previous name, Simultaneous Operations to Intersecting Runways (SOIR) has been conducted for many years. Perhaps the FAA should consider location specific authorizations for LAHSO which utilize hold short points not affiliated with a runway intersection.

ASY does not agree with the view that the recommendation defeats the original intent of the LAHSO program. To the contrary, FAA Order 7210.3P currently requires facilities to demonstrate that a valid operational need exists before implementing land and hold short operations based on an evaluation of such issues as capacity, delays and fuel savings (7210.3P 10-3-7 Land and Hold Short Operations). This is consistent with good risk management practice: LAHSO should be restricted in cases where the economic/capacity benefits do not outweigh incremental risks.

Statistical evidence provided by FAA-ATO indicates that, in some cases, LAHSO provides few efficiency gains. Since the implementation of LAHSO Notice 7110.199, several facilities have decided to terminate land and hold short operations—citing both the increased costs of the new requirements and the lack of efficiency benefits. Moreover, field visits indicate that, in some cases, capacity gains foregone as a result of terminating LAHSO have been recovered by implementing more efficient ground taxi and traffic management practices.

It is unclear why go-arounds are used as part of the LAHSO statistics in this paragraph. An overrun is a violation of the LAHSO. A go-around may not necessarily reflect a violation of the operation. Further, the go-around maneuver could be conducted during LAHSO for many reasons and it shouldn't be looked at as a poor operational practice. Pilots are taught that the go-around doesn't reflect lack of piloting skill or ability. Rather, pilots are taught that the *decision to go-around increases safety and demonstrates the pilot's ability to exercise good judgement and aeronautical knowledge….Although a go-around may create potential for aircraft conflict during LAHSO, a go-around during other non-LAHSO operations can also create similar safety issues. Thus, all things being equal, the go-around should not be considered in the historical rate for LAHSO safety analysis.*

ASY agrees with several points made in this comment: 1) A hold short point overrun is a violation of LAHSO, while a pilot-initiated go-around or "rejected landing" is not. 2) Under many scenarios, go-arounds increase safety and demonstrate a pilot's ability to exercise good judgment. 3) Rejected landings under some non-LAHSO scenarios may also create safety issues.

ASY did not intend to suggest in the risk assessment that hold short overruns *and* rejected landings should both be considered violations of LAHSO policy. Rather, the objective of the risk assessment was to identify areas where LAHSO may increase risks. The risk assessment (Table IV.1) compares four scenarios: 1) single-aircraft, 2) in-trail collision, 3) intersecting traffic ground collision, and 4) rejected landing scenarios. The table and accompanying text point out (as does the comment) that all four scenarios are associated with risks whether or not LAHSO is in effect (or even whether or not there is an intersecting runway). The critical question is: to what degree does LAHSO increase collision risks relative to a non-LAHSO situation?

In the case of rejected landings, the team concluded (and available event data affirmed) that the proximity of aircraft during a LAHSO rejected landing does increase risks. ASY concludes that the current strategy of collaboratively developing rejected landing procedures is a sound one. Moreover, if such procedures cannot be developed, consideration should be given to developing a "Type 3" control (i.e. sequencing).

Change the sentence to indicate that the February 9, 1999 agreement is with associations representing <u>airline</u> pilots.

ASY agrees with this comment and has revised the document accordingly.

3. ATA

Concerns for individual liability and the potential of perceived punitive action against individuals making mistakes is a primary yet unspoken aspect of LAHSO and adds difficulty to achieving consensus. Two of the three general means to control LAHSO risk could be enhanced by removing these concerns. This could lead to a more open and productive dialogue on the contributions controllers could make to enhancing the safety and efficiency of LAHSO operations.…We recognize that the setting of explicit rules to protect the intersection are very difficult, yet we know that experienced controllers develop many techniques that enhance the operation. These techniques include constant attention to the operation and early detection of potential abnormal operations, i.e., aircraft fast on the final or may land long. These experienced controllers then apply a technique of the prudent timing of instructions that can preclude simultaneous intersection incursions. This simple technique of staggering the *occurrence of aircraft at the intersection is referenced in the study and needs emphasis without regulatory separation standards.*

ASY generally agrees with this comment, in particular, the benefits of applying "a technique of the prudent timing of instructions that can preclude simultaneous intersection incursions." The risk assessment distills the sources of LAHSO risks into three elements: 1) exposure (i.e. the facilities and operators allowed to participate in the procedure), 2) the likelihood that the LAHSO aircraft cannot stop at the hold short point, and 3) the likelihood that there is a collision given that the LAHSO aircraft cannot stop at the hold short point. Current controls emphasize "2;" that is, they target the probability that the LAHSO aircraft does not stop at the hold short point. However, it is difficult to eliminate this risk due to the persistence of human errors and the presence of exogenous factors. Therefore, consideration should be given to "type 3" controls that address the probability of a collision *given a hold short overrun or rejected landing*.

The comment also notes that "concerns for individual liability and the potential of perceived punitive action against individuals making mistakes is a primary yet unspoken aspect of LAHSO and adds difficulty to achieving consensus." While ASY agrees with this observation, resolving issues of liability and punitive action is beyond the scope of this risk assessment.

Finally, the comment points out that "this document places relatively little emphasis on controller performance." The risk assessment reflects the findings of the LAHSO risk assessment working sessions. It should be noted, however, that many of the recommendations—e.g. coordination of declined LAHSO clearances, sequencing—will, if implemented, affect air traffic controllers.

4. RAA

In general RAA considers that the current LAHSO provides an acceptable level of risk; however the proposed "improved" lighting should be delayed and the determination of ALD's for the regional/commuter airplanes should be revised.

ASY agrees that improved LAHSO lighting schemes should be more thoroughly evaluated before implementation and this is reflected in recommendations 10 and 11 (regarding the non-automated and automated two-bar systems).

Available landing distances (ALD) were not explicitly raised during the risk assessment working sessions—in part since this issue was resolved in the February 9, 1999 agreement. While it is ASY's understanding that RAA did not have explicit input in that agreement, changing the ALD's in Notice 7110.199 is beyond the scope of the risk assessment (in other words, RAA is not contending that LAHSO is unsafe because the ALD's are too long) and would be more appropriately raised directly with the FAA Flight Standards Service.

5. SWA

Page VI Glossary- SWA, Southwest Airlines should be added since it participated in the risk analysis.

The document has been revised to reflect Southwest Airlines' participation.

Southwest Airlines strongly agrees with the recommended risk reduction strategies contained in the main body and appendix II of the draft report of July 9th, 1999. Further, Southwest Airlines is currently employing it's own safety risk management by not participating either actively or passively in Land and Hold Short Operations. We view the Office of System Safety risk analysis resulting in 29 suggested risk reduction strategies as sufficient evidence that the LAHSO program as it is currently conceived is inadequate in design with respect to safety and therefore premature in it's implementation.

Overall, one point should be clarified: this risk assessment is not suggesting that *all* recommended controls need be implemented in order to minimize risks. By classifying controls (and hazards) into three types—Type 1, restrict LAHSO approval; Type 2, reduce the probability of a hold short overrun or rejected landing; and Type 3, reduce the probability of a collision given an overrun or rejected landing—this assessment gives policymakers a menu of risk reduction options. For example, if LAHSO is not approved, then Type 2 and Type 3 controls are irrelevant. If traffic is sequenced, then the criticality of rejected landing procedures is lessened.

B. Comments Concerning Communications

1. AOPA

Anti-stuck microphone and anti-block radio technology. *By the placement of this suggested improvement separate from the long-term controls, it is inferred that this potential improvement could be implemented quickly. Currently, there aren't any general aviation aircraft operating in the national airspace system with this technology. It is a severe understatement to believe that this is a near term solution to some of the communications issues revealed during this risk assessment.*

The term "long-term" was used to identify concepts or technologies that were not yet developed (e.g. automated LAHSO lights). ASY agrees that a decision to implement anti-stuck/anti-block technologies, particularly for non-air carrier operations, is a benefit-cost question.

2. RAA

RAA consider that crew and air traffic training should address risk issues associated with communications.

C. Comments Concerning Crew Performance

1. AOPA

The assessment lists the non-air carrier LAHSO mix as an existing control. Although it exists in the current NOTICE, the FAA has assured AOPA that it will not be part of the Order soon to be released. This control should not be listed since it is temporary in nature and will not be part of the permanent order

By agreement (LAHSO risk assessment kickoff meeting, March 11, 1999), the risk assessment baseline included Notice 7110.199. That said, it is important to emphasize that ASY is not advocating that any particular group be arbitrarily excluded from certain operations in the National Airspace System (NAS). However, in those cases where procedures entail increased risks, it is important to identify, analyze, and, if necessary, control hazards as a precondition to participation.

Just as current LAHSO policies restrict certain types of air carrier operations based on potential risks, it may be necessary to develop criteria for non-air carrier LAHSO. During the risk assessment working sessions, several non-air carrier issues were identified: 1) the apparent increased likelihood of landing overrun accidents involving non-air carrier operations, 2) the apparent increased likelihood of equipment failure leading to overruns (accident or non-accident) involving non-air carrier operations, 3) the apparent increased likelihood of pilot flight hours to be (negatively) correlated to the incidence of overruns in non-air carrier operations. These issues suggest that LAHSO restrictions may need to address issues such as: 1) equipment requirements, 2) aircraft performance, 3) pilot training, 4) pilot experience (total and make-model), 5) whether sub-groups of the non-air carrier population can be appropriately identified by ATC, etc. These issues should be addressed before the implementation of non-air carrier-to-air carrier LAHSO is permitted as a national policy.

2. RAA

***Crew Performance- Landing Technique:** The new ALD criteria, …has placed several regional airplane types (e.g. B1900, Emb-120, Jetstream 4101) into totally unrealistic ALD groupings. Adding a 1,000 foot "penalty" to establish ALD provides a disproportionate penalty for smaller airplane types to qualify for LASHO. An ALD based simply on AFM criteria is overly conservative since it does not provide credit for reverse prop and thrust reverser deployment; Previous LASHO criteria provided credit for thrust reverser deployment on wet runways such that the wet runway ALD was less than the ALD was for dry runways! The commuter category airplanes without anti-skid have a significantly greater AFM ALD; While this may be valid in determining wet runway stopping distances, it becomes less valid if only dry runway LASHO is* *provided. The end result of having greater ALD's for the regional/commuter airplanes is that they will no longer qualify for LASHO on many "regional/commuter" runways; whether this results in more vectoring of the regional/commuter airplane types to fit into the larger airplane traffic flow onto the larger runways, remains to be seen.*

Tailwind/Crosswind, Gusts, Windshear: *Current policy provides an acceptable level of risk.*

Bar Lighting System: *The test that was conducted to validate the "improved" lighting configuration was incomplete. From the 777 cockpit vantage point, the pulsing lights at the alert point may have provided a beneficial visual cue to prepare the flight crew of the impending hold point. However the visual observation of the impending runway from a 777 cockpit is significantly different than from a regional/commuter airplane as it is rolling down the runway and further testing should be provided to determine whether the pulsing lights at the alert point will provide any value at all to the crew of a regional/commuter airplanes. In addition, the reluctance of one of the pilots who conducted the test to move the airplane beyond the pulsing white light (alert point) without further clarification indicates a unacceptable risk leading to confusion of the crew. Since Canada and Europe have no intention of installing two banks of LASHO lights, the opportunity for further confusion on what the lights actually mean, remains high. Lastly the placement of alert lights 1,000 feet prior to the hold point simply doesn't "fit" for many runways. Sometimes the alert point is at or near the runway intersection and the pulsing lights could create confusion for the other runway traffic. Clearly more studies to validate the safety of installing the "improved" lighting configuration should be accomplished.*

3. SWA

Page 8 next to last paragraph "One participant suggested adopting a regulation to establish minimum experience requirements (e.g., flight hours in type) for LAHSO." This mischaracterizes what the participant, Southwest Airlines, suggested which was to incorporate LAHSO into FAR 121.438. This regulation stops the second in command with less than 100 hour (sic) in type unless with a qualified check pilot from landing the airplane under various situations including at special airports, and with a crosswind component in excess of 15 knots. With as many safety concerns as exist for LAHSO surely it warrants inclusion in this regulation.

The risk assessment has been revised to more accurately capture the views of the commenter. However, ASY believes that the issue is broader than simply the second-in-command (SIC). Should the experience threshold be limited to the SIC? Should it apply generally to both pilots? Is 100 hours [or 75 hours in 14 CFR §121.438(b)] or some other number more appropriate? Does the statistical evidence support the conclusion that low flight time is related to increased LAHSO overrun risks?

D. Comments Concerning Rejected Landings

1. RAA

***Rejected Runway Criteria**: The rejected landing criteria…(fit) only a few airport intersections so if LASHO is to be conducted at most of the airports where it is presently conducted, additional rejected runway procedures need to be developed. This remains to be accomplished.*

(Note: This is currently being studied by a LAHSO team headed by FAA-AFS and FAA-ATO.)

2. SWA

The 2000 ft criteria for departing GA aircraft in determining the need for a rejected landing procedure is inadequate in almost all cases. "One participant noted that at least one set of instructions may require a VFR aircraft to fly into instrument meteorological conditions." This misstates what the participant, Southwest Airlines, noted. The "set of instructions" is the published rejected landing procedure itself. It is not just a VFR aircraft but an IFR aircraft that has accepted a visual approach clearance. The visual approach has no missed approach segment and therefore the aircraft must remain in VMC in the event of a rejected landing, possibly in direct conflict with the published rejected landing procedure. Considering the number of air carrier aircraft utilizing visual approaches on IFR flight plans this represents a larger set than just VFR aircraft.

The text has been revised to reflect this comment.

"Although the team did rate risks associated with rejected landings, the specifications of current controls are still being developed and so these ratings have limited value." Land and hold short operations are currently being conducted with the controls that were in place at the time of the teams rating of risk. Why does this become the category of the report not to have the teams rating published? This is particularly troubling considering the trouble and length of time the team spent in discussing the various issues related to the rejected landing situation. "Work between these groups to establish adequate procedures is continuing at the time of this writing." Neither Southwest Airlines nor Southwest Airlines Pilot Association has been made aware of any continuing work in this area.

Several factors led to the decision to omit risk rankings for rejected landings. The risks associated with existing rejected landing procedures (RLP) vary considerably between airports, and, therefore, a single national level ranking was seen as having limited value. The comment also suggests that the FAA can do a better job of communicating its progress on addressing LAHSO issues (including rejected landings) to all concerned parties.

E. Comments Concerning Wet and Contaminated Runways

1. ATA

The study suggests local officials establish procedures for the determination and timely notification of a wet runway. We suggest the development and application of national procedures with local implementation. Further, the LAHSO directive requires a dry runway which is interpreted as no visible moisture. We would suggest that research is required in order to determine the braking action required on a runway that may have moisture that would not impact braking action particularly on runways that are grooved and have other attributes such as acceptable gradient.

2. RAA

***LASHO- Wet**: The use of thrust reverser and reverse prop should be allowed in the determination of wet runway LASHO. LASHO wet should be re-instated.*

***Contaminated Runway:** This should be the responsibility of the airport tower in determining whether LASHO should/should not be conducted because of contamination. Pilots are under a continuing responsibility to report to the tower regarding changed conditions.*

ASY agrees that research is required to determine stopping performance on wet runways under a variety of conditions. There are, however, other hazards associated with wet/contaminated runways. For example, video documentation provided by FAA-ARP indicated that visually determining the hold short point could be extremely difficult in rain—particularly at night. The risk assessment concludes that other (non-brake performance related) hazards associated with LAHSO-wet must be thoroughly considered before a national policy is implemented.

F. Comments Concerning Other Hazards: RAA

***LASHO-Night**: . The level of risk for night operations is acceptable when weather conditions are favorable.*

***Aircraft Systems:** The level of risk is acceptable. MMEL dispatch procedures adequately address the safety issues.*

LAND AND HOLD SHORT OPERATIONS
RISK ASSESSMENT

I. Introduction

A. Objectives

More than 30 years ago, the FAA began allowing simultaneous operations on intersecting runways (SOIR) at certain U.S. airports under certain conditions. SOIR required a landing aircraft to stop before reaching an intersecting runway. In 1997, the concept was expanded to include hold short points before intersecting taxiways and at other points on the landing runway, under the designation of land and hold short operations (LAHSO). SOIR/LAHSO evolved from the observation that some landings did not require the full runway length and that this fact could be exploited to increase airport acceptance rates. Many parties have benefited from this procedure. Airports have been able to increase capacity without the need to physically expand the airport operating area, and this benefit has spilled over to surrounding communities which are sometimes opposed to airport expansion due to noise or environmental concerns. The procedure allows for greater availability of flights for passengers and fewer delays for private pilots. Commercial air carriers have also realized substantial economic benefits associated with increased system capacity and it follows, therefore, that commercial pilots have benefited as well in terms of an increased demand for pilots—i.e., more jobs and higher wages.

The objective of this analysis is to answer several fundamental safety questions regarding land and hold short operations:

- *What are the hazards associated with this operation?* That is, what are the conditions, events or circumstances related to LAHSO that could lead to an unplanned and undesired event (collision, near hit, runway excursion, etc.)?

- *What are the existing controls for this procedure?* What policies and/or restrictions apply to LAHSO? What types of equipment are required? What training is required of airport personnel, flight crews, and air traffic controllers? How are controls monitored and hazards tracked?

- *Given the hazards and controls, what are the residual risks associated with this procedure?* In other words, how well do the existing controls limit or mitigate the likelihood (frequency or probability of occurrence) and/or severity (number of injuries or fatalities, degree of aircraft or property damage, etc.) of a LAHSO accident?

- *How can residual risks be reduced?* Are there additional controls that could further reduce risks? In what areas could additional controls achieve the greatest degree of risk reduction?

It is also important to emphasize what this risk assessment does *not* do:

- *This assessment does not judge the acceptability of LAHSO risks.* The intent is to provide factual information concerning LAHSO risks based on analyses of statistical data and the input of subject matter experts who are familiar with and/or have participated in the procedure.

- *This assessment does not reconcile differences in risk perceptions among participants.* Rather, this study documents these perceptions, discusses the logic/rationale behind them, and, where possible, compares them to statistical and technical data. This approach does not prejudge the validity of a particular organization's risk perceptions based on assumed political, economic, or organizational self-interest.

B. Organization of the Study

Section II briefly discusses the history of land and hold short operations, and summarizes past risk studies. The risk assessment methodology is reviewed in Section III. Section IV describes in general terms the types of risks associated with these procedures and summarizes the statistical characteristics of reported LAHSO events. Detailed analyses of specific critical LAHSO issues—including an examination of statistical evidence, subject matter expert views, and quantification of accident likelihoods—are provided in Sections V (communications errors), VI (piloting technique), VII (rejected landings), VIII (wet and contaminated runways), and IX (other issues). Conclusions are offered in Section X.

Throughout this study, the terms "LAHSO aircraft" or "aircraft 1" refer to the aircraft that: 1) was issued and accepted a hold short clearance, 2) was issued and declined a hold short clearance, or 3) was expected to hold short (in those cases where it is unclear whether a hold short clearance was issued or acknowledged). "Full-length aircraft" or "aircraft 2" refers to the aircraft that: 1) was given a full-length landing clearance or a departure clearance to the runway intersecting the LAHSO runway, 2) was cleared to taxi across the LAHSO runway, or 3) crossed the "LAHSO aircraft" runway without appropriate clearance. Other aircraft are designated by numbers starting with "3": for example, "aircraft 3," "aircraft 4," etc. "Hold short overrun" is an event where the LAHSO aircraft traveled past the hold short point.

II. Background

A. Historical Background

The Federal Aviation Administration (FAA) has conducted simultaneous operations on intersecting runways (SOIR) as an approved procedure to enhance airport capacity since 1968. Under this procedure, Air Traffic Control could clear an airplane to land and stop before a designated “hold short” point, thereby permitting the movement of traffic on an intersecting runway. Originally, SOIR was implemented on an airport-by-airport basis, specifying which types of aircraft could land on the runway segments available for hold short operations and the procedures by which hold short clearances would be given. Procedures for conducting SOIR were eventually formalized in the Air Traffic Controller Handbook (FAA Order 7110.65). Aircraft types were grouped according to their required landing distances and these groupings were published in Appendix A to the handbook.[1] By the early 1990’s, SOIR was implemented at over 220 airports, including over 850 runway intersections.

In October 1993, the FAA formed a working group—consisting of representatives from the Flight Standards Service, Air Traffic, Airports and the Office of System Capacity—to study the implications of expanding SOIR to include landing and holding short of an intersecting taxiway or a designated point on the landing runway. This generalized concept was termed a “land and hold short operation” (LAHSO—see Figures II.1, II.2, and II.3). The task of the LAHSO working group was to review and, if necessary, revise the provisions of Appendix A and to formulate a national order that would establish basic procedural standards for determining where and when LAHSO would be conducted.[2]

In December 1993, Flight Standards requested that the Office of Aviation Safety (predecessor to the Office of System Safety) conduct a risk assessment of LAHSO in order to “build a firmer empirical justification for both a national LAHSO program and for implementation of LAHSO at individual airports.”[3] The initial risk assessment, completed in April 1995, did not quantify the risks associated with LAHSO, but it did identify several areas of concern including the potential for greater risk as the number of operations increases, and the paucity of relevant data.

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[1] “Simultaneous operations on wet runways have been conducted, under waiver from Air Traffic rules, at three major airports since 1988. An extensive set of other waivers have also been granted over the years allowing variations on SOIR to deal with uncommon runway configurations and non-standard uses of inactive runways or runway segments.” Federal Aviation Administration, Office of the Associate Administrator for Aviation Safety, *Land and Hold Short Operations: Preliminary Risk Assessment*, April 1995, p 2

[2] *Ibid*., p 3.

[3] *Ibid*., p 3.

Figure II.1.—Land and Hold Short of an Intersecting Runway

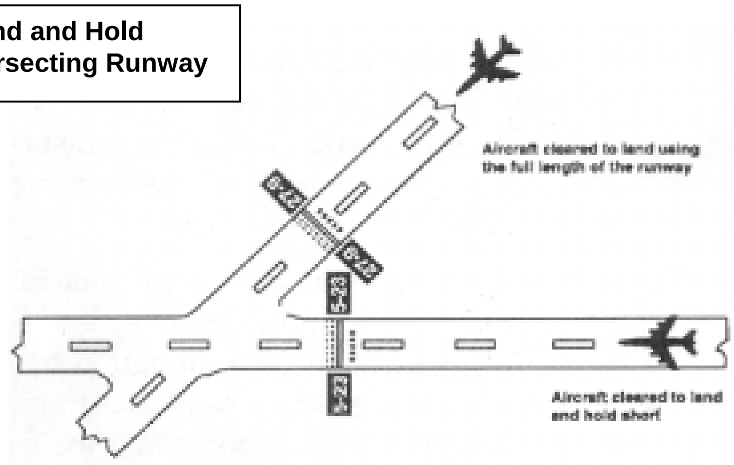
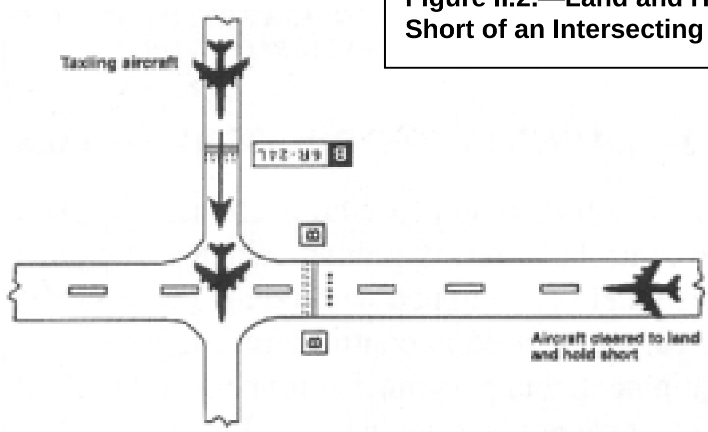


Figure II.2.—Land and Hold Short of an Intersecting Taxiway



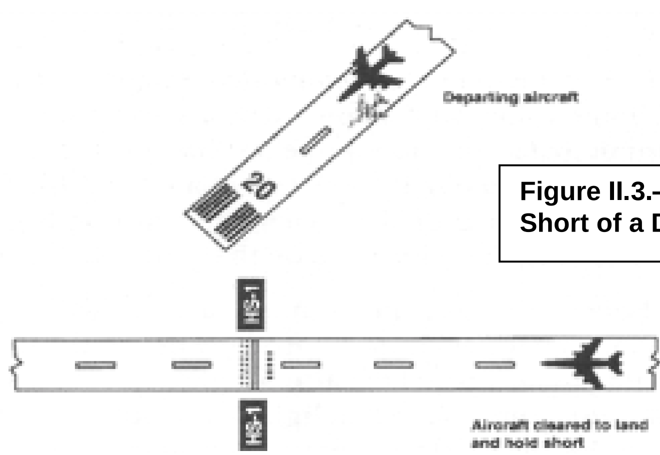
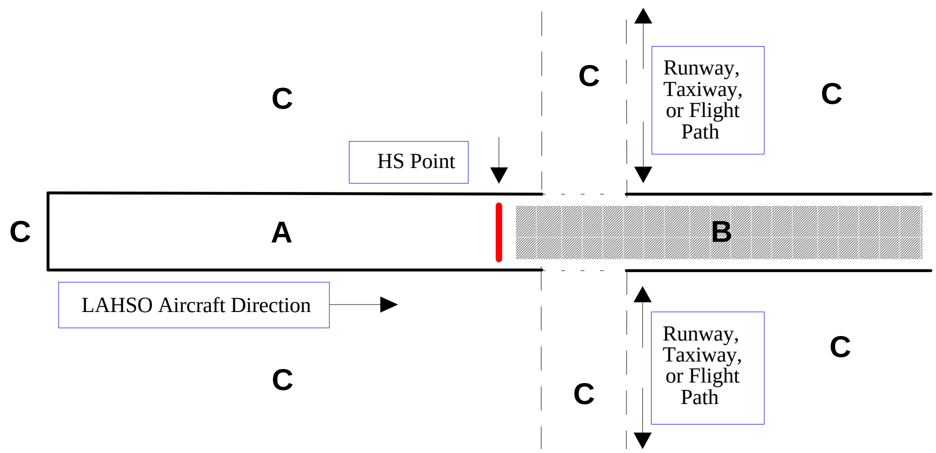


Figure II.3.—Land and Hold Short of a Designated Point

The 1995 study focused on nine types of LAHSO related collisions: combinations of the three types of obstructions involved [1) a vehicle (including another aircraft), 2) an obstruction, and 3) a person] and the three locations of the collisions [areas A, B, and C] (see figure II.4). Three hundred eighty-eight collision scenarios and approximately 180 initiating, or "root," causes were identified. One-hundred and fourteen root causes involved people (human factors), 58 involved regulations, 57 involved facilities and equipment, and 33 involved environmental factors.[4] However, risks associated with go-arounds and accidents that did not involve a collision between an airplane and another vehicle were not considered.

Figure II.4.—Collision Locations in the 1995 LAHSO Fault Tree Analysis
(Taken from: *Land and Hold Short Operations: Preliminary Risk Assessment*, April 1995)



While the 1995 risk assessment did identify accident "pathways", due to resource, time and data constraints it did not attempt to quantify accident likelihoods. In fact, even basic exposure data (estimates of the number of LAHSO clearances per year) were virtually nonexistent. A key recommendation of the study, then, was to "collect and document appropriate data to evaluate how safe and effective these [LAHSO] operations are."

As a result, Flight Standards requested that the FAA Office of Accident Investigation (AAI) design a survey to support a LAHSO demonstration program in the fall of 1995. AAI—working

[4] "Virtually all of the failure modes identified included one or more root causes involving human factors. Root causes involving mechanical failures are associated with a relatively small subset of all of the failure modes, often involve a required human factors failure, and are almost exclusively associated with well-known issues (e.g., aircraft braking failure on landing, headset failure following clearance acceptance, frequency congestion, and frequency interference) that are being managed to some extent. Failure to follow regulations or procedures are evenly spread across the fault tree and are involved in a wide variety of failure modes….Environmental conditions as root causes occur only in conjunction with one or more other types of root causes." FAA, Office of the Associate Administrator for Aviation Safety, *Land and Hold Short Operations: Preliminary Risk Assessment*, April 1995, p 18.

with the Office of Air Traffic Operations (ATO); the Flight Standards Air Carrier Operations Branch (AFS-200); the Technical Program Division (AFS-400); the Office of System Capacity, Capacity and Initiatives Division (ASC-200); and the Office of Airport Safety and Standards, Engineering and Specifications Division (AAS-200)—developed pilot data and controller data collection forms. The demonstration program involved Newark International Airport (EWR), Boston Logan International Airport (BOS) and Dallas Fort Worth International Airport (DFW).[5]

The AAI survey had four objectives:

- "Determine if pilots are advised in a timely manner that LAHSO is in effect;
- "Determine whether lights, signs, and markings are visible and understandable;
- "Identify communications problems between pilots-in-command and first officers, between pilots and controllers, or with pilots who land on adjacent runways; and
- "Determine whether LAHSO adds stress, strain, or undue wear on pilots and controllers and/or wear and tear on aircraft equipment."[6]

Generally, the survey results showed that pilots were comfortable with LAHSO at the demonstration airports. For example, 98 percent of the responding pilots at BOS, 100 percent of the responding pilots at EWR, and 88 percent of the responding pilots at DFW indicated that they were comfortable or very comfortable with the operation.[7] Ninety-six percent of the pilots at BOS, 82 percent of the pilots at EWR, and 84 percent of the pilots at DFW indicated that they did not have to adjust their normal flying technique or landing configuration. Nevertheless, survey respondents did raise several concerns, including: 1) rejected landing procedures during a LAHSO, 2) long landings, and 3) brake failures.[8]

On July 17, 1997 the FAA prescribed national "standards for use by Air Traffic, Flight Standards, and Airports in approving and conducting Land and Hold Short Operations" under FAA Order 7110.114.[9] Among its provisions, the Order called for the Office of System Safety to: 1) "maintain/update development of a risk assessment for LAHSO," 2) "provide analytical support essential to continuing trend analysis of site-specific incidents/accidents," 3) "coordinate with Air Traffic the publication of supplemental guidance and criteria to define and

[5] Federal Aviation Administration, Office of Accident Investigation, Safety Analysis Branch, *Land and Hold Short Operations (LAHSO) Demonstration Project Survey: Preliminary Report*, June 1997.

[6] *Ibid*., p 3.

[7] *Ibid*., p 19.

[8] *Ibid*., p 19-20. The AAI survey findings formed part of the basis for Flight Standards Information Bulletin (FSIB) for Air Transportation (FSAT) FSAT 95-02, "Requirement for Issuance of Land and Hold Short Operations (LAHSO) Operations Specifications for Operations Conducted under Federal Aviation Regulations (FAR) Parts 121 and 135," effective date 01-26-95.

[9] FAA Order 7110.114, *Land and Hold Short Operations (LAHSO)*, July 17, 1997.

systematically collect LAHSO operational error reports," and 4) "coordinate with Flight Standards the publication of supplemental guidance and criteria to define and systematically collect LAHSO pilot deviation reports."[10]

FAA Order 7110.114 generated a number of concerns, primarily in the pilot community, including: 1) the accuracy and adequacy of aircraft landing distance information contained in the order, 2) the need for LAHSO rejected landing procedures, 3) the need for vertical visual guidance, 4) the appropriateness of conducting LAHSO on a wet runway, and 5) the need for additional aircrew and controller training. While government and industry representatives debated these issues, at least one airport, Cincinnati/Northern Kentucky International, decided to discontinue LAHSO, citing safety concerns raised by Delta Air Lines pilots.[11]

In November 1998, the FAA formed a LAHSO Event Review Committee (ERC) to study reports of LAHSO incidents. Based on information exchanged at these meetings, Air Traffic Operations contacted several airports to ensure that correct procedures were being followed. At the same time, public awareness of the issues surrounding LAHSO increased—fueled, in part, by a LAHSO-related incident between two air carrier aircraft at Charlotte, N.C. airport in November 1998.[12] Later that month, ALPA announced that if "the FAA cannot adequately address ALPA's concerns by February 19. 1999, the union…will recommend that pilots not perform the 'land and hold short' (LAHSO) type of operation."[13]

On February 9, 1999, the FAA announced the completion of an agreement with associations representing airline pilots and airlines on a final set of procedures under which LAHSO would be conducted. The agreement covered five areas:

- *Runway surface*. Air carriers will conduct LAHSO only on dry runways until such time as manufacturers have provided actual demonstrated landing distance figures on wet runways for the aircraft in question.

- *Weather minima*. LAHSO would require minimums of 1500 ft. ceiling/5 mile visibility (or 1000/3 if visual vertical guidance is available on the LAHSO runway).

- *Training*. The FAA will issue a Flight Standards Handbook Bulletin that will specify that before an air carrier can conduct LAHSO, it will have a pilot training program for LAHSO.

[10] *Ibid.*, sections 11.a- d.

[11] Dias, Monica, "Airport Halts Risky Landing Method," *The Kentucky Post*, July 17, 1998.

[12] See, for example: "Pilots: Runway Crossings a Safety Hazard," *USA Today* (USAToday.com), November 13, 1998. "Pilots: Simultaneous Use of Intersecting Runways is Risky," CNN Interactive (CNN.com), November 24, 1998. "Pilots Protest Procedure After Air Scare," *USA Today* (USAToday.com), December 9, 1998.

[13] Air Line Pilots Association press release, "Pilots Union Sets Criteria for Acceptable LAHSO Runway Operations," December 14, 1998.

- *Rejected landing*. Only LAHSO configurations that do not require a rejected landing instruction, or for which a rejected landing instruction is published, may be utilized by air carrier aircraft.

- *Landing distance*. Runway landing distance for the particular aircraft conducting LAHSO will be the greater of the Simultaneous Operations on Intersecting Runway category length or the FAA approved Aircraft Flight Manual distance plus 1,000 feet for the configuration, environment, and the weight actually used for landing.

The agreement was subject to the findings of an updated risk analysis study. The parties resolved to review the agreement at the completion of the study or the first anniversary of the agreement, whichever came first.

In the winter of 1997-98, the Office of System Safety initiated a review of SOIR/LAHSO event data drawing information from the Aviation Safety Reporting System (ASRS), operational error and pilot deviation reports from the National Airspace Incident Monitoring System (NAIMS), National Transportation Safety Board (NTSB) accident reports, and FAA accident/incident reports. This review revealed an increase in the number of reported LAHSO events: total reports (combining all five databases) for the roughly 3 year period ending in the winter of 1997-98, exceeded the total number of reports for the 15-year period ending in 1994. It is not clear that this increase in reporting represented an actual change in risks; most of the increase was due to an increase in ASRS LAHSO reporting (with a lesser increase in pilot deviations).[14] However, this trend, combined with the content of specific report narratives, indicated that a follow-on to the 1995 study was warranted. Representatives from Air Traffic and Flight Standards were briefed on the results of the data review in the summer of 1998. On the basis of this review, and in accordance with Order 7110.114, the FAA formed a LAHSO risk assessment team the fall of 1998.[15]

The FAA team completed a preliminary analysis of LAHSO hazards in December of 1998; its findings were published in January 1999.[16] Subsequently, the team—expanded to include representatives from the general aviation community, commercial airline pilots, and commercial

[14] "Certain caveats apply to the use of ASRS statistical data. All ASRS reports are voluntarily submitted, and thus cannot be considered a measured random sample of the full population of like events. For example, we receive several thousand [ASRS reports of] altitude deviations each year. This number may comprise over half of all the altitude deviations which occur, or it may be just a small fraction of total occurrences. We have no way of knowing which….[T]he data reflecting reporting biases. These biases, which are not fully known or measurable, distort ASRS statistics." National Aeronautics and Space Administration, Ames Research Center, Aviation Safety Reporting System.

[15] As noted earlier, the FAA, ALPA, and ATA reached an interim agreement on LAHSO in February of 1999. That agreement restated the requirement for a risk assessment as part of a review process to draft a new LAHSO Order.

[16] FAA, Office of System Safety, *Land and Hold Short Operations (LAHSO) Risk Assessment Team Preliminary Report (Draft)*, January 1999.

air carriers—undertook a more detailed analysis of LAHSO risks targeting specific critical hazardous scenarios identified in the preliminary hazard analysis.

At the time of this writing, the FAA is undertaking a collaborative effort, involving regional and local authorities and national/local user representatives, to evaluate LAHSO at specific facilities across the country. This group will outline basic concepts for revised LAHSO procedures, and assist with the identification of required corrective actions. Additionally, action will be taken to establish data collection and quality control processes in order to validate procedures and identify risks.

B. Summary of Current Controls

The characterization of LAHSO as a trade-off between capacity and safety is an oversimplification. In fact, LAHSO is as much a question of *who* should bear responsibility for the safe conduct of the operation. In other words, it is also a trade-off between capacity and the level at which a given control is implemented (which may or may not be directly linked to safety). A brief description of the control hierarchy follows:

National Authority. At a national level, the FAA establishes broad guidelines for hold short operations which include:

- Criteria for the approval of LAHSO at a specific facility [e.g., FAA Order 7210.3P Facility Operation and Administration, AC 150/5340-1G Standards for Airport Markings, etc.].

- Criteria for the approval of LAHSO for a specific operator [e.g., FAA Flight Standards Information Bulletins (FSIB), Flight Standards Handbook Bulletin for Air Transportation (HBAT), etc.]

- Guidance for the air traffic control conduct of LAHSO [e.g., FAA Order 7110.65L Air Traffic Controller Handbook, FAA Notice 7110.199 Land and Hold Short Operations (LAHSO)].

Controls implemented at this level have the broadest impact, affecting all facilities and operators. A possible weakness in this level of control is that it may be difficult to exhaustively specify all hazards—some of which may be unique to individual airports, carriers, or pilots. Thus, a national policy may unnecessarily restrict operations at some sites where they could be safely performed and/or provide inadequate safety margins at other sites.

Airport. Approval for the conduct of LAHSO at a specific facility generally requires that the airport operator demonstrate:

- That there is justification for the procedure, e.g., that the procedure will alleviate delay problems or result in other economic benefits (FAA Order 7110.3P Chapter 10 Section 3), and

- That the facility is in compliance with FAA LAHSO requirements (e.g., markings and signs, lighting, friction measurement, etc.)

In some cases, an optimal risk strategy may call for facility-specific controls. LAHSO Notice 7110.199, for example, requires the development of LAHSO rejected landing procedures for specific LAHSO combinations if certain criteria are met.

Air carrier. Individual operators may also be required to demonstrate that appropriate training and procedures are in place before LAHSO is approved. These requirements vary by CFR part reflecting the different characteristics of various types of operations.

Air Traffic Controller. Controllers may also choose when to issue or not issue a hold short clearance. In addition to rules which specify the conditions under which LAHSO can be performed, a tower supervisor/controller-in-charge may terminate LAHSO "for any situation or weather condition which, in (his/her) judgment, would adversely affect land and hold short operations." [FAA Notice 7110.199 9.m.]

Pilot. Ultimately, it is the pilot who accepts or rejects a hold short clearance. In addition to national and local requirements, a pilot's decision-making may reflect considerations such as: 1) the presence of unusual environmental conditions (e.g., alignment of the runway relative to a rising or setting sun), 2) pilot condition (e.g., fatigue), 3) her/his personal level of comfort with the procedure, 4) familiarity with the airport, etc. Thus, an important consideration is the degree to which the LAHSO procedure design constrains pilot decision-making; particularly with respect to the acceptance/rejection of a LAHSO clearance.

III. Risk Assessment Methodology

As noted earlier, work on the updated LAHSO risk study began in the fall of 1998. Early in the process, the FAA team—consisting of representatives from the Air Traffic Operations Program, Flight Standards Service, Office of Airport Safety and Standards, and Office of System Safety—decided that the project required broader industry and government participation. However, it was also recognized that long-term involvement by the airlines, commercial airline pilots, private pilots, and the air traffic union in any LAHSO study was impractical because of resource limitations. The risk assessment, then, consisted of two phases: Phase I, the FAA internal preliminary analysis; and Phase II, FAA-industry working sessions.

A. Risk Assessment Phase I: FAA Preliminary Analysis

The FAA's preliminary internal analysis of LAHSO risks had two objectives:

- Develop a framework with which to identify, analyze, and rate LAHSO risks, and
- Identify LAHSO "hot spots" enabling the FAA-industry team to focus on the most critical safety issues.

Phase I work was divided into four steps, summarized below.

1. Preliminary Hazard List

In the first step, subject matter experts (SME)—representing the FAA Air Traffic Operations Program, Flight Standards Service, Office of Airport Safety and Standards, and the Office of System Safety—cataloged hazards related to LAHSO using a variant of Ishikawa's "cause and effect" diagram with main ideas forming the backbone and associated sub-element detail forming smaller off-shoots.[17] The resulting list of hazards included conditions associated with:

- *Environment*. E.g., winds, wake turbulence, precipitation, visibility.
- *Airport*. E.g., design of runway-runway and runway-taxiway intersections, lighting, signage, surrounding terrain, presence of obstacles/-structures, measurement and communication of runway conditions, maintenance, etc.
- *Aircraft*. E.g., probability and consequences of system failures, minimum equipment list (MEL) requirements related to the conduct of LAHSO, etc.

[17] "Cause and effect" diagrams are also referred to as "fishbone" or Ishikawa diagrams after originator Kaoru Ishikawa. See, for example, Ishikawa, Kaoru, *Guide to Quality Control*, (Tokyo, Japan: Asian Productivity Organization), 1982.

- *Flight crew*. E.g., crew experience, airport familiarity, landing technique, communications procedure, intra-crew workload management, etc.

- *Air traffic system*. E.g., design of rejected landing procedures, coordination between approach and local, availability of LAHSO-relevant information on the Automatic Terminal Information Service (ATIS), noise abatement procedures.

2. Construction of Accident Scenarios

In the second step, the hazard information obtained in step 1 was used to generate LAHSO accident scenarios. There are many ways to develop these scenarios; this analysis used an event tree approach. The event tree modeled a notional land and hold short operation beginning with a set of initial conditions (airport and environmental conditions), continuing through the operation itself (including ATC-flight crew communications, aircraft function, crew performance); and ending with the outcome (e.g., whether the LAHSO aircraft stops at the hold short point). (See Table III.1)

Table III.1.—Description of Event Tree Questions/Variables

	Variable/Question	Possible Values
Initial Conditions		
Aircraft Types	LAHSO Aircraft Type	Commercial, General Aviation
	Full-length Aircraft Type	Commercial, General Avaition
Environment	Runway Condition	Dry, Wet, Other Contaminants
	Wind Conditions	Calm, Tailwind, Crosswind
	Light Conditions	Day, Night
Operations		
Communications	Air Traffic Controller	Yes LAHSO, No LAHSO
	LAHSO Aircraft	Yes LAHSO, No LAHSO
	Full-length Aircraft	Yes LAHSO, No LAHSO
Aircraft Operations	LAHSO Aircraft Systems	No malfunction, Brake System Malfunction, Other System Malfunction
	LAHSO Aircraft Flight Crew	Normal, Error
	Full-length Aircraft Operations	Departure, Arrival, Taxi, Go-around
Operation Outcome		
	LAHSO Aircraft	Hold Short, Hold Short Overrun, Go-Around, Excursion
	Outcome	Normal outcome, single aircraft event, collision event

Each level or question in the tree can be interpreted as a variable that can take on one of several values—in this case the values indicate the presence or absence of a hazard. A particular scenario (tree branch or path), then, is a chain or sequence of specific hazardous conditions and events that could result in one of several types of accidents (or no accident). It is important to note that the tree is a high level analysis of accident scenarios; accordingly hazard conditions are considered at a high level. A more detailed analysis of specific hazards is undertaken in Phase

II. In addition, the event tree logic permits non-catastrophic outcomes even if the LAHSO aircraft does not hold short, and catastrophic outcomes even if the LAHSO aircraft does not overrun the hold short point.

3. Severity/Likelihood Matrix

In the third step, the FAA team constructed scales and associated criteria to rate accident scenarios in terms of severity and likelihood (see Table 4). For example, an accident scenario involving a part 121 turbojet in which the aircraft is destroyed or where there are multiple fatalities is classified as "F," the most severe type of accident scenario. If this scenario is also very likely, it is given a likelihood rating of "1"; so its assignment in the matrix would be "F1"—an accident scenario that would be identified as a "critical path" requiring more analysis.

It should be emphasized that these scales were not intended to withstand rigorous analytical scrutiny, but were simply a means to broadly classify risks and determine which issues merited more in-depth analysis. Scenarios that were associated with multiple fatalities and high likelihood would be given more focus relative to scenarios that involve minor damage and low likelihood. It is worth noting that even "near hit" scenarios were judged to be critical under certain likelihood conditions.

Table III.2: Preliminary severity/likelihood matrix

	Level B	**Level C**	**Level D**	**Level E**	**Level F**
	Near hit. No casualty/property damage.	No fatality serious injury; part 91/135 aircraft substantial damage.	Nonfatal accident, one serious injury, w/o subst. Damage to part 121 jet a/c. Possible damage to piston or turboprop.	Serious: one fatality; or at least one serious injury and part 121 turbojet a/c substantial damage	Major: part 121 turbojet destroyed; or multiple fatalities; or 1 fatality and a part 121 turbojet aircraft destroyed.
1 High Likelihood $>10^{-3}$					
2 Medium Likelihood 10^{-3} to 10^{-5}					
3 Low Likelihood 10^{-5} to 10^{-6}					
4 Very Unlikely 10^{-7} to 10^{-9}					
5 Extremely Remote $<10^{-9}$					

	Critical—must address risk in FAA-industry working group
	Lower priority—address in Phase II if resources available
	Risk does not require further analysis

4. Rating of Accident Scenarios

In step four, FAA SME's rated the accident scenarios generated in Step 2. To fully understand the dynamics of each scenario and the role of hazard conditions, a hypothetical "minimal control" environment was assumed. Other controls—for example limitations on student pilots, weather minimums, etc.—were assumed not to be present. The ground rules for this analysis were:

- Aircraft receive and accept a clearance to hold short of a designated hold short point, and

- The available landing distance (ALD) is 1.67 times the demonstrated landing distance (DLD) (consistent with 14 CFR 121.195).

Team members then were asked to provide conditional likelihood estimates—that is, estimates which assumed a given condition. For example, the probability of a wet runway collision depends on: 1) the probability of a wet runway, 2) the probability of a hold short point overrun given a wet runway, and 3) the probability that two airplanes would be in the intersection at the same time in the event of a hold short point overrun (on a wet runway). FAA team focused on the conditional questions #2 and #3; in other words, the team assumed that the probability of a wet runway was 1.0 and then evaluated the risks associated with a collision at the intersection as a result of a wet runway.

B. Risk Assessment Process II: FAA-Industry Working Sessions

In Phase II of the risk assessment process, the team was expanded to include representatives from industry and other interested organizations within FAA. The expanded team included participants from the following organizations:

- Air Line Pilots Association (ALPA)
- Air Transport Association (ATA)
- Aircraft Owners and Pilots Association (AOPA)
- Continental Airlines (COA)
- National Air Traffic Controllers Association (NATCA)
- National Air Transport Association (NATA)
- National Business Aviation Association (NBAA)
- Regional Airline Association (RAA)
- Southwest Airlines Pilots Association (SWAPA)
- Southwest Airlines (SWA)
- FAA-Air Traffic Operations Program (FAA-ATO)
- FAA-Flight Standards Service (FAA-AFS)

- FAA-Office of Airport Safety and Standards (FAA-AAS)
- FAA-Office of System Capacity (FAA-ASC)
- FAA-Office of System Safety (FAA-ASY)

1. Project Scope and Ground Rules

On March 11, 1999, the FAA convened a kickoff meeting to review the FAA's preliminary work, establish the project scope and ground rules, and plan a course of action for the second phase of the risk assessment. As noted earlier, many industry participants were unable to commit to a long-term research project. Instead, the working sessions were scheduled for two consecutive days, with a wrap-up session to be held later.

The main goal of the FAA-industry working sessions was to maximize the likelihood that all aspects of an issue were thoroughly considered. Consensus was not a requirement—in fact, disagreements were seen as a healthy way to stimulate thinking. Discussion was terminated (by the facilitator) only when new ideas were exhausted and the team seemed to be rehashing old debates. The team agreed to define the scope of the risk assessment to include: 1) incremental LAHSO risks, and 2) Consideration of risks related to LAHSO to include hold short instructions issued after landing. Incremental LAHSO risks refer to risks that arise because of the hold short instruction. For example, a collision involving a landing aircraft and a truck that has transgressed the runway is not an accident scenario unique to LAHSO. The hold short clearance, in this case, does not clearly result in an additional or incremental risk relative to a standard landing clearance.

However, additional restrictions on LAHSO may create incentives to circumvent current controls and increase the use of hold short instructions after landing. Thus, the team agreed to consider hold short or turn-off instructions issued after landing as part of this risk assessment.

2. Working Session Format

For each of the critical areas identified in the FAA preliminary study, the FAA-industry team evaluated hazard controls. This consisted of three steps:

- *Enumerate and discuss existing controls*. Existing controls consist of FAA policies and regulations governing the conduct of land and hold short operations; equipment requirements; policies and procedures implemented by facilities and operators, etc. For example, a control for the wet runway hazard is to prohibit the conduct of LAHSO if the runway is wet.

- *Discuss possible ways in which the controls can fail*. In this step, the team discussed hypothetical ways in which the controls could fail drawing from information obtained during the Preliminary Hazard List discussions and from the experience of subject matter experts. For example, the prohibition of LAHSO-wet could fail if: 1) runway moisture is not detected, 2) the runway condition, if detected, is not communicated to the air traffic controller or pilot, or 3) the controller chooses to circumvent LAHSO controls by issuing a hold short instruction on landing rollout.

- *Evaluate residual risks*. Each organization then was asked to give its assessment on whether existing controls limited LAHSO risks to an acceptable level, or if additional controls were necessary.

Two criteria were used to rate risks: For a given level of severity, risks could be evaluated by the *total accident probability*. For example, the probability of a wet-runway LAHSO collision (assuming that LAHSO-wet is permitted) depends on: 1) the probability that LAHSO is conducted on a wet runway, 2) the probability of a hold short overrun given the wet runway, and 3) the probability that two airplanes are in the intersection at the same time in the event of a hold short overrun. Therefore, all other things equal, if the probability of a wet runway is very small, the total probability of a wet runway LAHSO collision is small (and, potentially, acceptable).

However, team members could also rate a risk as unacceptable based on its *conditional probability*. In other words, risks could be rated assuming the probability of the hazard condition is one. For example, the risks associated with LAHSO-wet could be found unacceptable even if the probability of a wet runway LAHSO is very small, but the likelihood of a collision given a wet-runway LAHSO is very high.

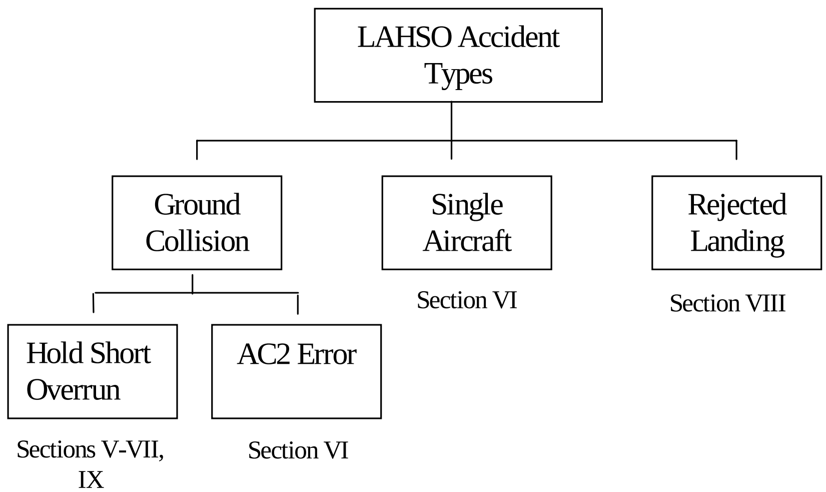
At the end of the 2-day working session, participating organizations were asked to provide possible additional controls (in those cases where risks were judged to be unacceptable). This “homework” assignment had two parts: 1) suggest possible controls that could be implemented by your own organization, and 2) suggest other controls that would involve other organizations.

IV. Overview of LAHSO Risks and Policy Options

A. Types of Accident Risks

The accidents considered in this analysis fall into three groups: 1) ground collisions (that arise either because of the inability of the LAHSO aircraft to hold short or an error on the part of the full-length aircraft), 2) ground accidents that do not involve a collision, and 3) accidents that involve a LAHSO aircraft rejected landing. These accident types are summarized in Figure IV.1.

Figure IV.1.—LAHSO Accident Types and Report Organization



In the absence of controls, LAHSO could introduce additional landing risks simply due to the increased demands of the procedure and the proximity of traffic. One way to understand the potential incremental risks associated with LAHSO is shown in Table IV.1 which compares four broad accident scenario types (the rows of Table IV.1) for three types of operations (the columns of Table IV.1). *It is important to note that Table IV.1 is meant only to give a descriptive comparison of accident scenarios.*

Single aircraft accidents. Many single aircraft accident scenarios—i.e., events that may result in injuries or aircraft damage, but do not involve a collision with another vehicle—do not constitute risks unique to a LAHSO. For example, there is little evidence to suggest that pilots conducting LAHSO are more likely to land short or forget to extend the landing gear relative to pilots performing a non-LAHSO landing (all other things equal). However, LAHSO could introduce additional single-aircraft risks. For example, uncertainty on the part of the full-length aircraft (that is, the aircraft on the runway intersecting the LAHSO runway) could result in evasive maneuvering (rapid deceleration, premature rotation, ground maneuvering, etc.) to avoid a perceived potential collision.

Table IV.1.—Types of Landing Risks by Operation

	Single Runway	Intersecting Runway (No LAHSO)	Intersecting Runway LAHSO
Single Aircraft Events (not involving a collision w/ another vehicle)	• Overrun/excursion • Stall • Landing short • Omission of pre-landing items (e.g., extend gear) • Evasive maneuvering to avoid vehicle, animal, etc. (e.g., incursion)	• Overrun/excursion • Stall • Landing short • Omission of pre-landing items (e.g., extend gear) • Evasive maneuvering to avoid vehicle, animal, etc. (e.g., incursion)	• Excursion • Stall • Landing short • Omission of pre-landing items (e.g., extend gear) • Evasive maneuvering to avoid vehicle, animal, etc. (e.g., incursion) • Evasive maneuvering to avert hold short overrun (e.g., excursion) • Evasive maneuvering by full-length aircraft (e.g., rejected takeoff, premature rotation, emergency stops)
In-Trail Collision Risk	Landing aircraft collision w/ • Preceding aircraft • Subsequent aircraft • Aircraft or vehicle during incursion	Landing aircraft collision w/ • Preceding aircraft • Subsequent aircraft • Aircraft or vehicle during incursion	LAHSO aircraft collision w/ • Preceding aircraft • Subsequent aircraft • Aircraft or vehicle during incursion Accident involving full-length runway operation: • E.g., Conflict involving position and hold aircraft.
Intersecting Runway Collision Risk	**N/A**	• Accident due to loss of separation w/ inters. traffic. - Human error - Communication failure	• Accident due to failure to hold short. - Human error - Equipment failure - Communication failure - Conflict w/ preceding aircraft - Runway condition - Environ. conditions • Accident not involving overrun. (e.g., aircraft 2 lands on wrong runway).
Go–Around Collision Risk	• Limited risk	• Accident due to loss of separation w/ inters. traffic: - Human error - Communication failure	• Landing aircraft go-around collision with full-length aircraft due to: - Human error - Communication failure - Conflict w/ preceding aircraft - Runway condition - Environ. conditions

In-trail aircraft accident risks. Similarly, LAHSO and non-LAHS operations share common in-trail collision scenarios. However, LAHSO may contribute to increased in-trail collision risks for full-length traffic. For example, full-length departures in position and holding for take-off clearance could be delayed due to uncertainty over the hold short clearance thereby causing a conflict with arriving aircraft.

Intersecting runway collision risks. In the absence of LAHSO, a collision involving aircraft at the runway intersection would be a result of a breakdown in processes and procedures that ensure separation (e.g., as a result of human error, miscommunication, etc.). LAHSO introduces additional hazards in that even if the process functions as designed—that is, even if pilots apply appropriate flying technique and controllers follow appropriate procedures—a collision could still result due to an exogenous condition (e.g., the failure of an aircraft system, runway contamination, etc.).

Go–Around Accident Risk. LAHSO may also introduce incremental risks in the case of pilot initiated go-arounds. This follows since, in the event of a rejected landing, the LAHSO aircraft could be operating in much closer proximity to other traffic. Moreover, it is possible that the operation itself may increase the likelihood of rejected landings, with pilots choosing to go around rather than risk a runway incursion (following, say, a high, fast approach) or due to a potential conflict with an aircraft that is slow to depart the runway. It should be emphasized that the risk of a midair collision after a rejected landing by a LAHSO aircraft represents a potentially greater hazard than aircraft colliding on the ground after a hold short overrun.

B. Statistical Analysis of LAHSO Risks

LAHSO data must be used cautiously. Aviation Safety Reporting System (ASRS) reports, for example, are not investigated and are subject to reporter biases. National Airspace Information Monitoring System (NAIMS) data—including pilot deviations (PD), vehicle/pedestrian deviations (VPD), and near mid-air collisions (NMAC)—while subject to investigation, may not capture all accidents, incidents, or errors in procedures. National Transportation Safety Board (NTSB) and FAA Accident/Incident Database System (AIDS) data are generally restricted to events that involve some level of aircraft damage or injury and, therefore, may not give a complete picture of risks.

Detailed exposure data (tabulations of the numbers of land and hold short operations by, say, operator, aircraft type, time of year, etc.) are also scarce. So, estimates of event rates can vary substantially depending on several key assumptions.

The statistical information that follows must be interpreted with these limitations in mind. The statistics were used more to validate/evaluate expert judgment, and not necessarily to drive conclusions on LAHSO risks. *It is important to emphasize that these results are more useful as an indicator of the relative criticality of various LAHSO risks rather than as a measure of the statistical probability of LAHSO accidents.*

1. Estimates of the Number of LAHS Operations Per Year

The 1995 preliminary risk assessment estimated SOIR activity through a process of elimination; subtracting from total operations those operations known to be ineligible for SOIR. This process involved:

- Determining the total number of operations in the NAS, by all aircraft types
- Determining how many of these were conducted at airports conducting SOIR
- Determining how many operations were permitted given the maximum available hold short landing distance (by aircraft type and airport)
- Determining how many of these operations were conducted in VMC
- Determining how many of these operations were conducted during peak periods
- Determining how many of these were conducted during dry runway combinations.

On this basis, the 1995 study concluded that no more than 2.1 million SOIR operations were conducted at the top 50 FAA towered airports, or about 10% of total operations at these sites.[18] This calculation was interpreted as an upper bound since it did not take into consideration the limiting effects of wind conditions, air carrier practices (at the time Delta Airlines and British Airways did not permit their pilots to accept hold short clearances[19]), or the discretion of individual pilots. The top 50 airports, however, represent 30 percent of total operations, and, as noted above, at the time of the 1995 study over 200 airports were authorized to conduct SOIR. Thus, the 1995 study left unanswered the question of how many total hold short operations are conducted per year.

Table IV.2.—Estimated Number of Land and Hold Short Operations, 1998

		FAA Towers	**Contract Towers**	**Total**
1	Number of Facilities	288	161	449
2	# Facilities Reporting LAHSO	78	3	81
3	Total Operations all Facilities (000's)	53,798	12,432	66,230
4	Total Ops LAHSO Facilities (000's)	18,601	291	18,892
5	Pct LAHSO Ops (LAHSO Facilities)	14.21	3.12	14.04
6	Estimated 1998 LAHSO Ops (000's)	2,644	9	2,653

[18] "Among the top 50 airports by activity, 30 currently conduct SOIR." FAA, *Land and Hold Short Operations: Preliminary Risk Assessment*, *Op. cit.*, p 10.

[19] *Ibid.*, p 7.

Notes for Table IV.2:

1. Number of FAA and contract Airport Traffic Control Towers (ATCT)—FAA Office of Aviation Policy and Plans (APO) (http://www.apo.data.faa.gov/).
2. Number of FAA ATCT's reporting LAHSO use—FAA Air Traffic Operations Program survey (ATO).
3. Total operations, all facilities—FAA-APO.
4. Total operations, LAHSO facilities—FAA-APO, FAA-ATO.
5. Percent LAHSO operations to total operations at facilities reporting LAHSO use—FAA-ATO.
6. Estimated 1998 LAHSO operations—row 5 times row 4.

In the fall of 1998, the FAA Air Traffic Operations Program (ATO) conducted a survey of land and hold short operations nationwide. Eighty-one airports reported using LAHSO; these airports account for approximately 30% of total operations (at all FAA and FAA-contracted facilities).[20] The survey found that, LAHSO constituted approximately 14% of all operations at these 81 facilities.[21] Under the assumptions that all LAHSO-airports responded (and responded correctly) and that the time period sampled is representative of an entire year of operations, then total LAHSO activity would be approximately 2.6 million per year or about 4% of total operations at all airport traffic control towers (ATCT).

This result is complicated by three considerations. First it is possible that not all airports used the same definition of "total operations." In FAA-APO statistics, for example, an arrival and departure are counted as two operations, but some airports recorded LAHSO proportions in excess of 50%. For example, Chicago O'Hare reported that 80% of "total" operations were LAHSO. Second, it is unclear whether some airports that actually conduct LAHSO failed to report. Finally, it is possible that the sampling period is not representative of an entire year of operations. An adjustment for the first consideration would tend to make the estimated LAHSO total lower; an adjustment for the second consideration would tend to make the estimated LAHSO total higher. The effect of the third consideration is ambiguous. For these reasons, the Office of System Safety recommends that a more comprehensive survey of LAHSO activity be conducted. (See Section X: Conclusions.)

2. LAHSO Data

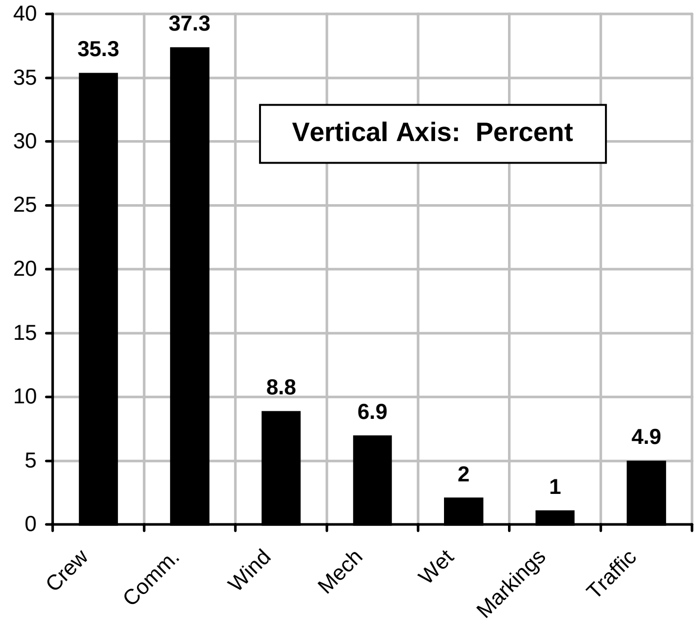
The statistical characteristics of LAHSO reports are based on an evaluation of data taken from the five-year period ending in December 1998. During that period, over 120 LAHSO reports were received by the ASRS and NAIMS systems. (For a complete listing of events, see

[20] FAA, Office of Aviation Policy and Plans, air traffic data for 1997: Total operations for all FAA and FAA-contracted facilities—64.6 million. Total operations for facilities reporting LAHSO use—19.0 million. The number of "airport operations" is defined as the number of arrivals and departures from the airport at which the airport traffic control tower is located.

[21] FAA Air Traffic Operations Program Survey, "Operations at ATCT's Reporting Utilizing LAHSO," 1998. Total reported operations—9.8 million. Total LAHSO—1.4 million.

Appendix II.) Not surprisingly, the data show that human factors—flight crew and controller performance, communications errors, etc.—appear in a significant proportion of LAHSO reports. Figure IV.2 shows the distribution of LAHSO ASRS/NAIMS event characteristics, and Table IV.3 shows how these characteristics are distributed by Federal Aviation Regulations part.

Figure IV.2.—Distribution of LAHSO ASRS/NAIMS Report Characteristics, 1994-1998



Notes for Figure IV.2:

1. A single report can have multiple characteristics (so percentages do not necessarily sum to 100%).
2. Crew: reports where piloting technique was mentioned as a factor in an ASRS or NAIMS LAHSO report.
3. Comm: reports where communications errors were mentioned as factors in an ASRS or NAIMS LAHSO report.
4. Wind: reports where the wind condition was mentioned as a factor in an ASRS or NAIMS LAHSO report.
5. Mech: reports where the malfunction or failure of an aircraft system was mentioned as a factor in an ASRS or NAIMS LAHSO report.
6. Wet: reports where a wet runway was reported.
7. Markings: reports where the pilot reported that he had difficulty in determining the location of the hold short point.
8. Traffic: reports where landing traffic had a conflict with preceding traffic.

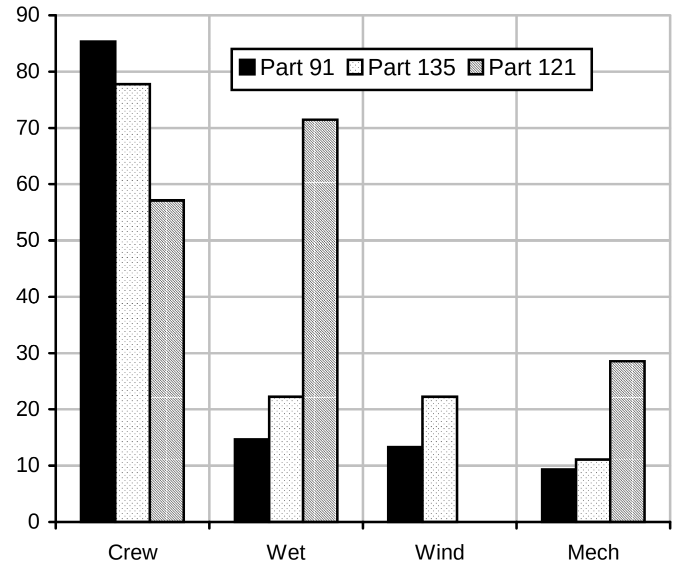
Table IV.3.—Distribution of LAHSO Report Characteristics by CFR Part, 1994-1998

	Crew	Comm	Cross/Tail Wind	Mech	Conflict w/ preceding traffic	Wet	Markings
Part 91	65.6%	28.1%	3.1%	6.3%	6.3%	0.0%	3.1%
Part 121	19.4%	40.3%	11.3%	4.8%	4.8%	3.2%	0.0%
Part 135	50.0%	50.0%	16.7%	33.3%	0.0%	0.0%	0.0%
Total	35.3	37.3%	8.8%	6.9%	4.9%	2.0%	1.0%

As noted above, ASRS data in particular must be interpreted carefully. They probably do not give a complete record of events and they are subject to the biases of the reporter. (On the other hand, ASRS LAHSO reports often are corroborated by multiple reports from different parties referring to the same event and by pilot deviation and operational error reports. See Appendix II.) One way to analyze the data in Table IV.3 and Figure IV.2, then, is to compare it to data drawn from other types of accident/incident reports.

This comparison is made by asking the generic question: Why do airplanes exhaust or overrun the available landing distance? Figure IV.3 shows the distribution of contributing factors for NTSB landing overrun accidents by 14 CFR (Title 14 of the Code of Federal Regulations) parts 91, 121, and 135 for the 1994-1998 period. (The characteristics are taken from the “probable cause” section of the accident report—see footnote 22.) The overrun distribution generally mirrors the distribution of LAHSO ASRS/NAIMS characteristics (at least with respect to contributory factors common to LAHSO and overrun events).

Figure IV.3.—Characteristics of NTSB Landing Overrun Accidents[22]



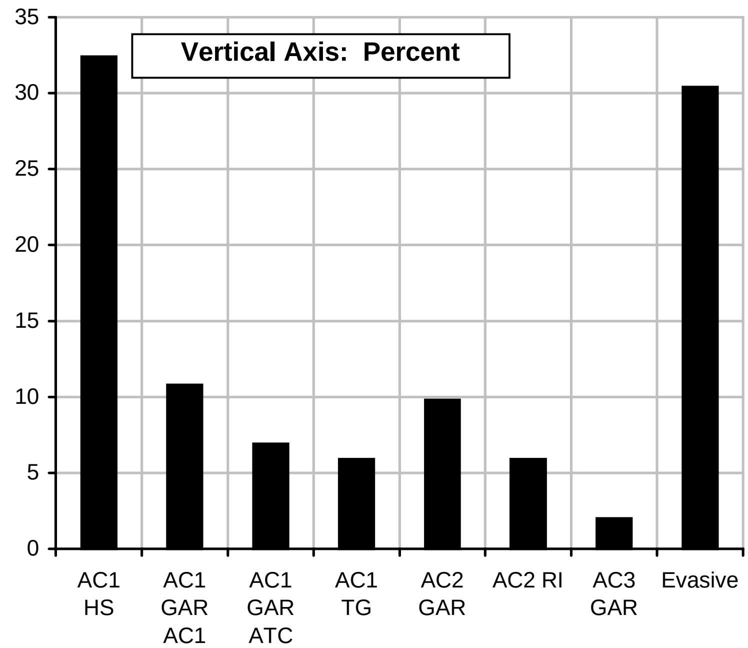
Crew performance was a dominant characteristic in both the ASRS/NAIMS and NTSB distributions. Environmental conditions—wind and wet—were the second most frequently sited factors, followed by mechanical system failure or partial failure. However, "conflict with a preceding aircraft" was not cited as a factor in any NTSB overrun report. ("Communications", understandably, are not sited in the NTSB reports since communications in this context only refers to the understanding between the controller and flight crews that one aircraft must hold short of a designated point that is not the runway end.) LAHSO events were also classified with respect to the event outcome. The results are shown in Figure IV.4 and in Table IV.4.

Table IV.4.—Distribution of LAHSO ASRS/NAIMS Outcomes by CFR Part, 1994-1998

	AC1 HS	AC1 GAR AC1	AC1 GAR ATC	AC1 TG	AC2 GAR	AC2 RI	AC3 GAR	Evasive
Part 91	46.88%	25.00%	0.00%	18.75%	18.75%	0.00%	0.00%	40.63%
Part 121	22.58%	4.84%	11.29%	0.00%	6.45%	8.06%	3.23%	22.58%
Part 135	60.00%	0.00%	0.00%	0.00%	0.00%	20.00%	0.00%	60.00%
Total	32.35%	10.78%	6.86%	5.88%	9.80%	5.88%	1.96%	30.39%

[22] An analysis of NTSB overrun accidents that: 1) involve a landing aircraft, 2) involve a landing on a paved runway surface, 3) do not involve an excursion off the side of the runway. The characteristics cited were taken from the "probable cause" section of the accident summaries (using the accident/incident summaries from the NTSB website). For example, NTSB incident IAD96IA044 describes the probable cause as: "Excessive airspeed was maintained by the captain during the approach/landing phase of the flight, which resulted in an overrun and an encounter with soft/wet terrain. Factors relating to the incident were: the pilot's failure to attain the proper touchdown point, the wet runway condition and partial failure of the anti-skid brake system." Therefore, this event involved characteristics "crew", "wet", and "mech."

Figure IV.4.—LAHSO ASRS/NAIMS Outcomes, 1994-1998



Notes for Figure IV.4 and Table IV.4:

1. AC1-HS—LAHSO aircraft overruns the hold short point.
2. AC1-GAR-AC1—LAHSO aircraft goes-around (pilot initiated).
3. AC1-GAR-ATC—LAHSO aircraft goes around (air traffic initiated)
4. AC1-TG—LAHSO aircraft executes a "touch-and-go"
5. AC2 GAR—Full-length traffic goes around
6. AC2 RI—Full-length traffic goes through the intersection even though the LAHSO aircraft did not accept a hold short clearance.
7. AC3 GAR—A third aircraft (not the LAHSO aircraft or the intersecting traffic) goes around.
8. Evasive—A pilot reports having to make an evasive maneuver in order to avoid a perceived collision threat.

In about one-third of the ASRS/NAIMS "events"[23], the "LAHSO" aircraft did not stop at the hold short point; a rate of about 7 hold short overruns per year.[24] The LAHSO aircraft either self-initiated a go-around or executed a "touch-and-go" in approximately 15% of the reports.

[23] "Event" is loosely defined as an accident, incident, deviation, or some other type of error reported in the ASRS/NAIMS data. In some cases, there are multiple reports corresponding to one event.

[24] In some cases, reporters claim that they were not given a hold short clearance even though intersecting traffic was cleared.

The full-length traffic executed a go around in approximately 10% of the reports. In about a third of the events, one or more aircraft reported having to make an evasive maneuver (or stop abruptly) in order to avert a perceived collision threat.

3. Baseline Overrun/Go-Around Probability Estimates

The operational and event data discussed above can be used to estimate event rates. (As discussed elsewhere in this report, these rate estimates could be subject to considerable bias. As will be discussed below, these data form a baseline against which subject matter expert opinion can be validated and are not, by themselves, accurate measures of risk.)[25]

- *Hold short overruns per year*. During the five-year period 1994-1998 ASRS/NAIMS logged 33 hold short overrun reports, or 6.6 per year.

- *Hold short overruns per million operations*. There were 8 hold short overruns in 1998.[26] Given that there were an estimated 2.653 million land and hold short operations in 1998, the overrun rate is approximately 3 per million operations.

- *Pilot initiated go-arounds or touch-and-goes (LAHSO aircraft) per year*. During the period 1994-1998 ASRS/NAIMS logged 17 reports of pilot initiated go-arounds or touch-and-go landings, or 3.4 per year.

- *Pilot initiated go-arounds (LAHSO aircraft) per million operations*. There were 3 pilot initiated go-arounds reported in 1998. Given that there were an estimated 2.653 million land and hold short operations in 1998, the go-around rate is approximately 1.13 per million operations.

Some observers have suggested that the amount of analysis directed to LAHSO seems to be disproportionate to the risks. Runway incursions, they note, number several hundred per year relative to LAHSO hold short overruns, which number less than a dozen per year. Table IV.5 compares event rates for various types of accidents and incidents. FAA and contract ATCT conducted approximately 66.2 million operations in 1998. There were about 300 runway incursions (RI) during that year, yielding a rate of about 4.5 RI per million operations. In

[25] What is the risk of a collision given a hold short overrun? During the five-year period 1994-1998 there were 33 reported hold short overruns. If the rate of hold short overruns has historically been proportional to the total number of operations, then during the twenty year period 1979-1998 there were about 120 hold short overruns. There was one known collision during this period, in 1983, a Cessna 421B collided with a B727 resulting in minor aircraft damage (in 1991, a small single-engine airplane overran its hold short point and was caught in the wake of a departing commercial jet resulting in minor aircraft damage) This suggests a collision rate of about 0.02 per million operations, or about 1 in 120 hold short overruns. Clearly, this estimate is subject to considerable variability, but it does indicate that a baseline collision rate estimate of between 1-in-100 to 1-in-1000 hold short overruns is a reasonable approximation.

[26] It is worth noting that 5 of the eight reports were found in both the ASRS and NAIMS databases. Two of the three remaining ASRS events involved multiple reports—in one case five different reporters.

comparison, there were about 2.65 million LAHSO in 1998 and 8 hold short overrun events, yielding an overrun rate of about 3.0 per million operations. The combined LAHSO hold short overrun and pilot-initiated go-around rate is estimated to be approximately 4.1 per million operations. These data suggest that, in terms of event rates, RI and LAHSO risks are comparable.

4. Variables Which Could Affect Future LAHSO Risks

As we have seen earlier, the probability of a LAHSO accident depends on many variables—changes in which could cause future probabilities to be different from observed historical probabilities. In this section we qualitatively discuss these variables.

LAHSO operations. All other things equal, the annual probability of a LAHSO accident depends on the number of LAHSO performed. As noted elsewhere, until recently little effort has been made to systematically collect LAHSO data. Thus, it is not clear if LAHSO has been increasing over time, and, if it has, whether the increase has been less-than-, greater-than-, or equi-proportional to total operations. What follows are estimates of current and future LAHSO event rates based on different assumptions about the U.S. aviation system.

According to *FAA Aerospace Forecast Fiscal Years 1999-2010*, total operations at FAA and contract ATCT's increased by approximately 0.5% per year between 1990 and 1998. But projected growth for the next twelve years is expected to average nearly 2% per year; an increase of nearly 16 million operations by 2010. Under the assumption that the number of land and hold short operations grows equiproportionally to the total (and assuming that about 2.7 million LAHSO are performed annually at present) the expected number of LAHSO in 2010 would be approximately 3.2 million.

Table IV.5.—Comparison of Accident, Incident and Event Rates, 1998

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
					Accident/Event Rates (see notes)				
Operations		**Numbers of Events**			**Pt 121 Rates**		**RI**	**LAHSO**	
All ATCT	LAHSO	Runway Incursions	LAHSO Overruns	LAHSO GAR	All Accid.	Fatal Accid.	RI Rate	Overrun Rate	Event Rate
66.2	2.7	~300	8	3	4.65	0.10	4.5	3.0	4.1

Notes:

1. Total number of operations for 1998, FAA and Contract ATCT (source: FAA-APO).
2. LAHSO operations for 1998 estimated from FAA-ATO survey (see Table IV.2).
3. Runway incursions for 1998.
4. LAHSO ASRS/NAIMS hold short point overruns for 1998.
5. LAHSO ASRS/NAIMS pilot-initiated go-arounds for 1998.
6. Pt 121 (scheduled/non-scheduled) accident rate per million departures. Note that ATCT operations count an arrival and a departure separately. (Source NTSB)
7. Pt 121 fatal accident rate per million departures. (Source NTSB)
8. Runway incursions divided by all ATCT operations.

9. LAHSO overruns divided by LAHS operations.
10. LAHSO overruns plus go-arounds divided by LAHS operations.

In areas where the system is already constrained by available runways, however, increased traffic would require runway construction and/or measures that would increase the utilization of existing runways. It is important to note that LAHSO is not the only means to increase capacity given a fixed supply of runways. For example, the converging runway display aid (CRDA) enhances controllers' ability to precisely separate aircraft on merging paths, permitting closer spacing for arrivals on intersecting runways.[27] However, it is plausible that, in the absence of additional restrictions, LAHSO will also be used to increase acceptance rates at physically constrained facilities. It is possible, therefore, that a significant fraction of the anticipated 16 million increase in operations will be achieved through LAHSO.

Table IV.6.—Workload Forecasts for FAA and Contract Towers, 1990-2010[28]

Activity Measures	**Historical**		**Forecast**			**Forecast Annual Growth Rate**
	1990	**1998**	**1999**	**2000**	**2010**	**1998-2010**
Number of Towers						
FAA Towers	403	288	288	288	288	
FAA Contract Towers	24	161	161	161	161	
Total	427	449	449	449	449	
Aircraft Operations (millions)						
Air Carrier	12.9	14.3	14.6	15.0	20.0	2.8
Commuter/Air Taxi	9.0	10.2	10.4	10.6	13.3	2.2
General Aviation	38.1	38.1	38.7	39.4	45.2	1.4
Itinerant GA	20.8	22.1	22.5	22.9	26.3	1.5
Local GA	17.2	16.0	16.2	16.5	18.9	1.4
Military	2.9	2.8	2.8	2.8	2.8	0.0
Itinerant MIL	1.5	1.4	1.4	1.4	1.4	0.0
Local MIL	1.4	1.4	1.4	1.4	1.4	0.0
Total Operations	62.8	65.3	66.5	67.7	81.2	1.8
Total less Military	59.9	62.5	63.7	64.9	78.4	1.9
LAHSO						
= Growth Rate (1.9%)	?	2.60	2.65	2.70	3.26	1.9

[27] Conversations with tower controllers at one site having CRDA estimated that CRDA increased acceptance rates by about 20%. LAHSO was also an approved procedure at this facility. Controllers estimated that LAHSO increased acceptance rates by about 40%. Note that CRDA is not used as a separation aid in conjunction with a LAHSO involving two arriving aircraft.

[28] FAA Office of Aviation Policy and Plans, *FAA Aviation Forecast, 1999-2010*, Table I-4, March 1998 (taken from the FAA-APO publications website).

Probability of a hold short overrun or rejected landing. The historical rate of hold short overruns and pilot initiated go-arounds is about 4.1 per million operations. All other things equal, the overrun/go-around rate must decline faster than the growth rate of LAHSO in order for collision risks to be reduced.

It is important to note that in many cases, pilots reported that they declined a land and hold short clearance, but traffic nonetheless crossed their runway (in some cases requiring pilot action). These events, while not included in the hold short overrun count, suggest greater collision risks than the hold short overrun numbers alone imply. Also, evidence suggests that ASRS and NAIMS data do not give a complete count of all hold short overrun events. As one participant suggested, “no harm, no foul,” thus an event may not be reported in any voluntary or mandatory system.

Risk Transfer. Another consideration is that some LAHSO controls represent a transfer of risks. For example, new FAA-Flight Standards guidelines require a rejected landing if a specified touchdown zone cannot be attained. While this may reduce the risks associated with a hold short overrun, it may increase risks associated with a rejected landing.

Probability of a collision given a hold short overrun or rejected landing. Changes in LAHSO policy (e.g., regarding night or wet LAHSO) could increase collision risks even if the hold short overrun rate is unchanged or declines. Moreover, several participants expressed concerns that increased LAHSO use could increase the probability of a collision given a hold short overrun. This follows because increasing LAHSO rates could be achieved by closer sequencing of intersecting operations.

C. Policy Options

Policy options can be understood in the context of Figure IV.5 which illustrates ground collision accident scenarios. As noted earlier, the annual probability of a LAHSO-related accident depends on: 1) R_L, the frequency or rate of LAHSO use, 2) P_{HSO}, the likelihood of a hold short overrun or rejected landing (which is conditional on the presence of hazardous conditions), and 3) P_{COL}, the probability that two airplanes are in the same place at the same time. The FAA, then, is confronted with three general means to control LAHSO-risks:

- Restrict the application of LAHSO
- Adopt controls that reduce the likelihood of a hold short overrun or rejected landing
- Adopt controls that reduce the likelihood of collisions given a hold short overrun or rejected landing

Restrict the application of LAHSO. Current regulations require that a facility “determine that a valid operational need exists before conducting simultaneous takeoff and landing or simultaneous landing operations.” This need may be based on factors such as airport capacity/acceptance rates, arrival/departure delays, and fuel consumption (FAA Order 7210.3P). It is not clear, however, that a consistent national policy is being applied to this process. Survey data collected by the FAA Air Traffic Operations Program (FAA-ATO), for example, show that LAHSO constitutes less than one percent of total operations at some facilities.

Regulatory and equipage requirements create economic disincentives for LAHSO at locations where the regulatory costs exceed expected benefits. In addition, FAA Notice 7110.199 limits air carrier LAHSO to specific airports (listed in Appendices I and II). However, given the inherent incremental risks associated with LAHSO (see Section IV), the FAA should consider applying more rigorous approval criteria that would restrict LAHSO only to those airports where there is a significant demonstrated economic/capacity need.

Reduce the likelihood of hold short overruns/rejected landings. Most existing requirements control LAHSO risks by targeting the factors that may cause hold short overruns; for example, limitations on tailwinds and wet runways. In some cases, these controls may transfer risks; lessening the probability of a ground collision, but potentially increasing the probability of an airborne accident. A key question, then, is whether these measures reduce accident risks to an acceptable degree.

Reduce the likelihood of collisions given a hold short overrun. If the probability that the pilot cannot stop before the hold short point is unacceptably high, then additional controls must be applied to reduce the likelihood of a collision given the hold short overrun. In fact, some policies, either currently in effect (e.g., LAHSO-night) or under consideration (e.g., LAHSO-wet), may increase the conditional probability of a collision given a hold short overrun in that they may reduce the likelihood that intersecting traffic will be able to "see-and-avoid."

One possible control is to sequence aircraft so as to minimize the likelihood of a collision even if the LAHSO aircraft cannot stop before the hold short point—for example, using computer algorithms/displays.

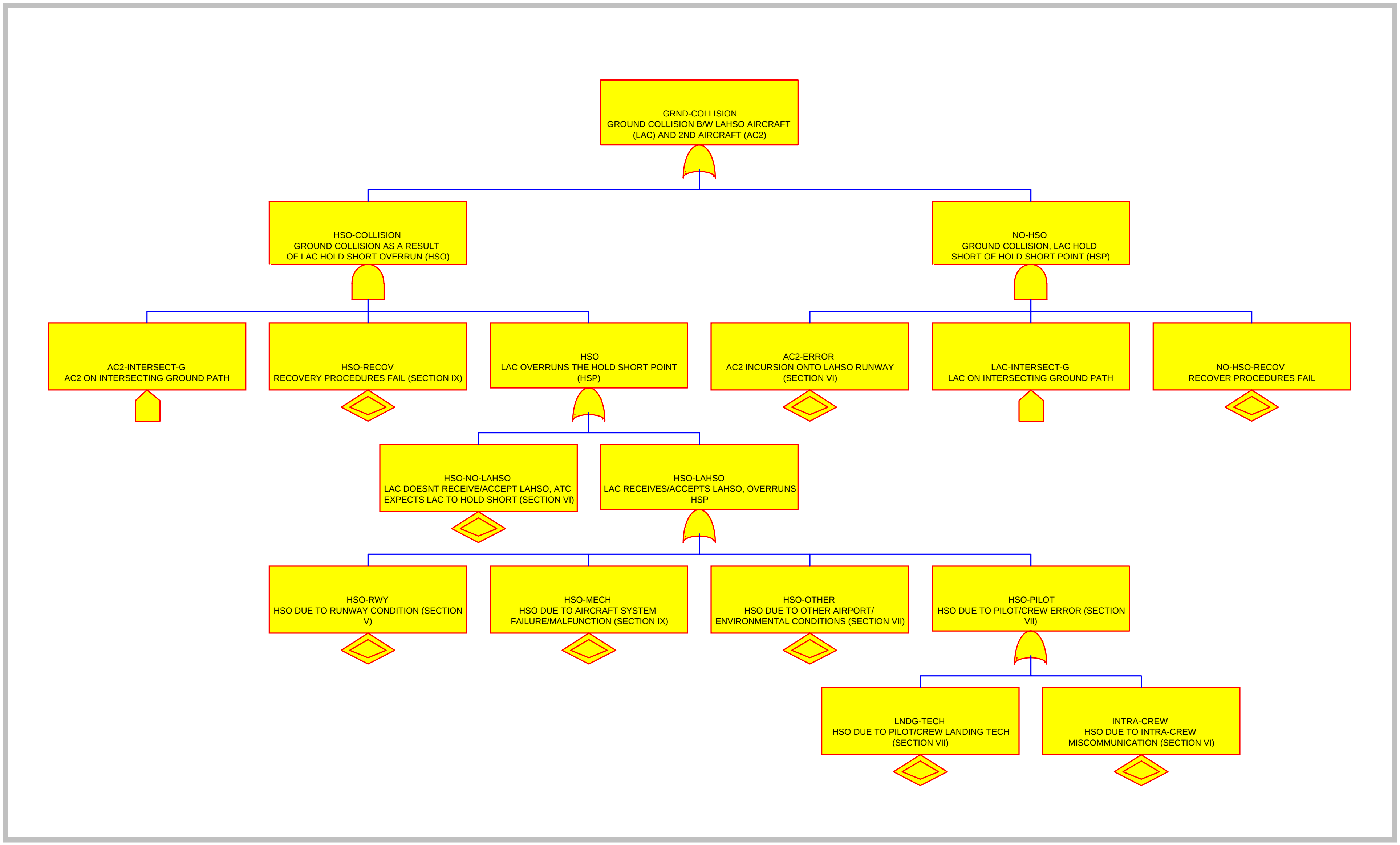
The Office of System Safety believes that the following risk reduction strategies should be considered:

1. **Approval of LAHSO at specific airports**. The FAA should consider applying more rigorous approval criteria that would restrict LAHSO only to those airports where there is a significant, demonstrated economic/capacity need.

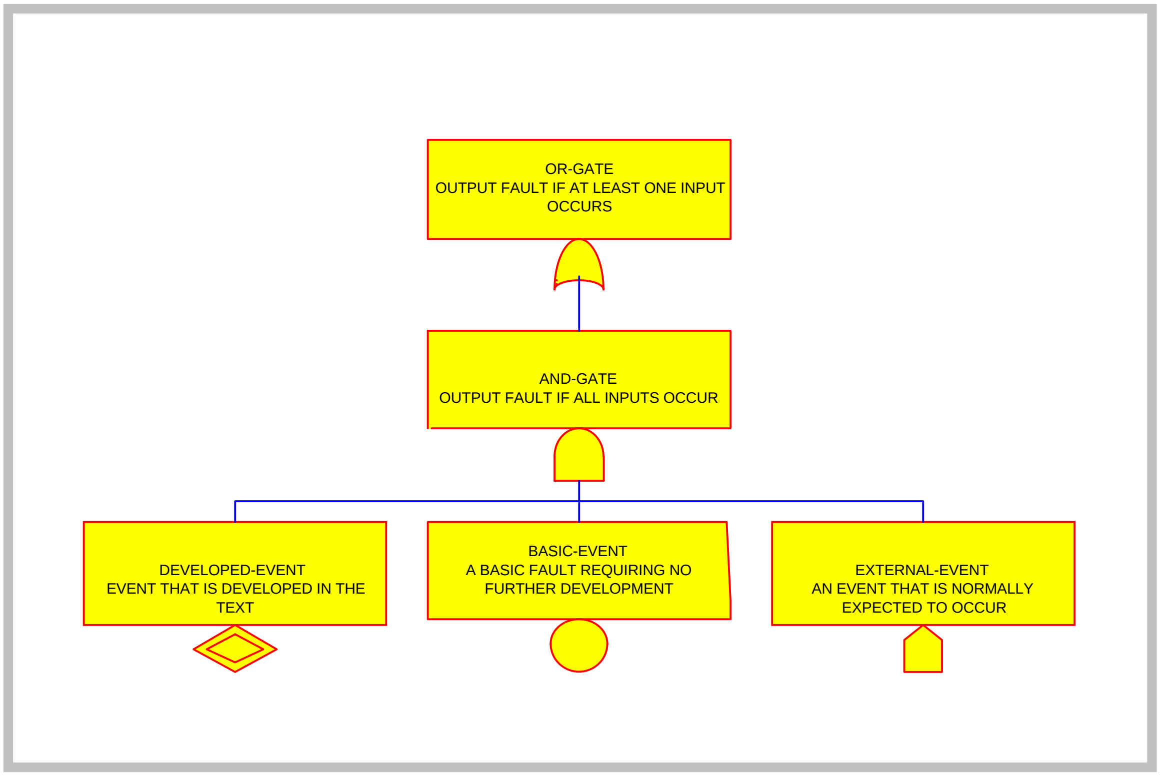
2. **Controls to minimize P_{COL}.** The FAA should consider developing procedures whereby LAHSO and full-length aircraft are sequenced to minimize the likelihood of a collision even if the LAHSO aircraft cannot stop before the hold short point (e.g., using tables or computer algorithm/display tools).

The following sections review critical accident scenarios. For each generic scenario, this report: 1) presents the reasoning for the FAA internal team judgment, 2) describes existing LAHSO controls applicable to the scenario, 3) discusses possible ways in which the controls could fail to adequately limit or mitigate the risk, 4) presents the FAA-industry team's assessment of "residual risks," that is the risk associated with the specific scenario given the existing controls, and 5) enumerates possible additional controls.

Figure IV.5.—Ground Collision Fault Tree



Key to Figure IV.5

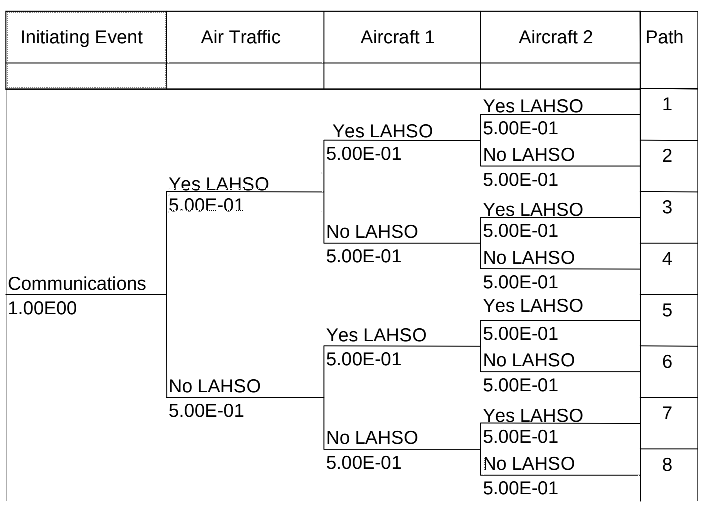


V. Risks Associated with Communications Errors

A. Summary of FAA Team Findings

The FAA team concluded that several accident scenarios related to communications errors constituted critical risks that should be addressed in the FAA-industry working sessions. The team modeled communications errors as a binary state problem with three agents: 1) air traffic control, 2) LAHSO aircraft flight crew, and 3) full-length aircraft flight crew. Each agent either believes that a LAHSO clearance has been issued and accepted or that the operation in which they are an active or passive participant is not a LAHSO. (The "active" LAHSO participant is the LAHSO aircraft, the "passive" participant is the intersecting traffic.) Therefore, there are 2^3 or 8 scenarios. These scenarios are illustrated in Figure V.1: the communications event sub-tree. In the tree, "yes" means that the agent understands that LAHSO is "on;" that is, that a land and hold short clearance has been issued and accepted. "No" means that the agent believes that LAHSO is not on. "Yes/No/Yes," for example, means that the controller believes that LAHSO is on, the would-be LAHSO aircraft believes that LAHSO is not on, and the full-length aircraft believes that LAHSO is on. A communications error, then, is defined as a condition where the air traffic controller state is different from either the LAHSO aircraft state or the full-length aircraft state. (Note that this analysis can be further complicated by including the possibility of multiple controllers, and flight crew members.)

Figure V.1.—LAHSO Communications Event Sub-Tree:
Misunderstood LAHSO Clearance



(Note: "Aircraft 1" is the LAHSO aircraft, and "Aircraft 2" is the intersecting, full-length clearance.)

Path 1 is a benign scenario (normal LAHSO communications) in which air traffic and the LAHSO aircraft and full-length aircraft understand that a LAHSO clearance has been issued and accepted. Path 8 corresponds to the case where normal separation standards are applied (no LAHSO in effect); a LAHSO was either not issued, or was issued, correctly declined, and the hearback was correct.

Table V.1.—Selected ERC Data Regarding Air Traffic/Flight Crew Communications

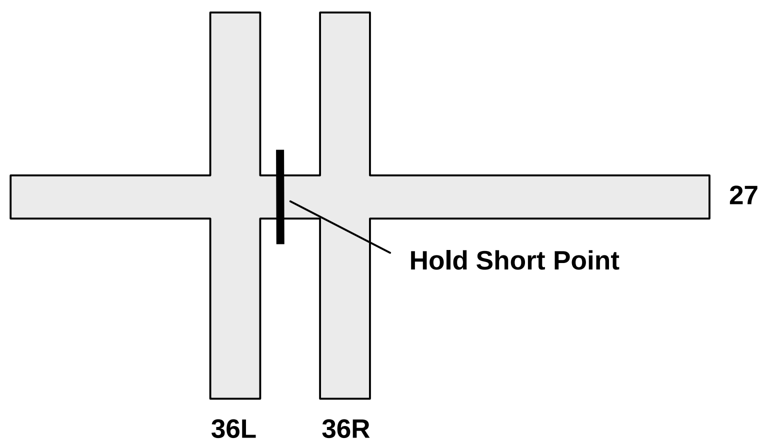
Hazard	Selected Events
ATC does not recognize pilot declining LAHSO clearance.	*ORD ASRS 376854*. Air carrier states four times "Negative Hold Short" with air carrier cleared for takeoff on intersecting runway. Takeoff clearance cancelled. *ORD ASRS 401884*. B-727 advised approach they would be unable to LAHSO. Twr cleared to LAHS of Twy S. Op Spec precluded operation, lead to heated discussion on freq. *ORD ASRS 415997*. B-727 advises "negative LAHSO," tower assigns LAHSO.
Inadvertent situational assumption ATC perceives LAHSO clearance w/o actual issuance of clearance.	*DFW ASRS 385036*. Air carrier cleared to land full length w/ aircraft crossing downfield. ATC forgot to issue LAHSO. *BDL ASRS 381825*. Air carrier and light twin cleared to land on intersecting runways without LAHSO restriction. *ELM ASRS 376269*. Air carrier notices another air carrier in flare on intersecting rnwy when cleared to land without LAHSO. Reporter noted collision narrowly avoided.
Frequency congestion hinders communication. Pilot attempting to decline LAHSO.	*BOS ASRS 379041, 378875*. Air taxi failed to hold short due to tailwind, wake turbulence. Could not communicate inability to stop due to freq. congestion. Air carrier on intersecting rnwy had just begun TO roll when incursion occurred. *MIA ASRS 414424*. Crew chastised for not advising approach control of Negative LAHSO and is issued go-around. Crew indicates approach was very busy.
Lack of knowledge of other a/c intention due to less than adequate communications	*LAS ASRS 385990*. B-737 makes short TO due light load, passes over A-320 doing go-around after A-320 unable to hold short. Two tower frequencies in use. (NMAC)

The team discussed each error path at length in order to fully consider the dynamics and consequences of the different types of miscommunications. It concluded that not all errors produce a critical scenario. *Ceteris paribus*, paths 5, 6, and 7 were judged to be non-critical errors as long as non-LAHSO air traffic separation standards are maintained—essentially, these cases reduce to non-LAHS operations. In other words, some additional controller or crew error would have to occur in order for a conflict to exist (e.g., the controller gives a departure clearance to the full-length aircraft knowing that the intersecting traffic is not going to hold short).

The team identified three critical paths from figure V.1. Paths 3 and 4 are "classical" communications errors in which the LAHSO aircraft believes it has the full runway. The team also judged that scenario 2 involves a critical hazardous scenario due to the potential for high-speed braking that could ensue if the pilot of aircraft 2 suddenly sees unexpected intersecting traffic.

Misunderstood LAHSO clearances do not constitute the only types of communications error relevant to LAHSO, however. An additional accident scenario involves a communications error that occurs independently of a correctly issued and accepted land and hold short clearance. Figure V.2 illustrates this scenario. In this case, the LAHSO aircraft has accepted a landing clearance to runway 27 to hold short of 36L. The full-length traffic is cleared to land to 36L (and is correctly advised to expect traffic holding short). Under this scenario, the full-length aircraft incorrectly lands on 36R. This scenario can be generalized to include incorrectly interpreted takeoff clearances or taxi instructions. Note: this general accident scenario does not necessarily require a communications error as an "initiating event." It could also be the result of poor situational awareness on the part of the full-length aircraft. This scenario is considered in the "Communications" section since accident/incident data suggest that communications errors are a frequent factor in this type of error.

Figure V.2.—Notional LAHSO Runway with Two Intersecting Parallel Runways



In summary, this study considers three types of communications initiated accident scenarios:

- Hold short overrun and collision resulting from a miscommunication between air traffic control and the LAHSO aircraft.

- Single aircraft accident involving evasive maneuvering by the full-length aircraft as a result of miscommunication between air traffic control and the full-length aircraft.

- Collision as a result of an incursion by the full-length aircraft onto the LAHSO runway as a result of miscommunication between air traffic control and the full-length aircraft.

B. Description of Existing Controls

FAA Notice 7110.199 specifies several procedures governing LAHSO communications. These are summarized below:

- When LAHSO are expected to be used, an announcement shall be made on the Automatic Terminal Information System (ATIS). [Section 9.h.]

- When LAHSO is conducted at locations not served by an ATIS, or the ATIS is out of service, pilots shall be advised on initial contact or as soon as practicable thereafter. [Section 9.i.]

- Traffic information shall be exchanged and a read back shall be obtained from the landing aircraft with a LAHSO clearance. [Section 9.k.]

- An acknowledgement (of the hold short clearance?) shall be received from the crossing aircraft/vehicle. [Section 9.k.]

- Foreign air carrier and foreign commuter aircraft are not to be issued LAHSO clearances. [Section 7.h.]

- Air Carrier aircraft shall not land or depart on a runway when a non-air carrier aircraft is landing to hold short of the air carrier runway. [Section 7.i.]

Additional controls are contained in FAA-Flight Standards FSIB and Aeronautical Information Manual (AIM) material for general aviation and air carrier operations:

- Pilots should read back the LAHSO clearance.

- When the ATIS is acknowledged and upon initial contact, the pilot in command will advise if the LAHSO clearance cannot be accepted.

C. Hazards That Could Degrade Existing Controls

Controller-LAHSO pilot communication error scenarios are illustrated in Figure V.3—Communications Error Fault Tree. Generally, communications errors could be the result of:

- An error by the controller (e.g., failure to issue a LAHSO clearance, failure to correctly hear and acknowledge a declined LAHSO clearance),

- An error by the pilot (e.g., accepting a LAHSO clearance without understanding what it requires), or

- A combination of both (e.g., readback/hearback error on the part of the controller and one or more flight crews).

- Difficulty in maintaining visual separation from another aircraft when a rejected landing is initiated after a LAHSO clearance has been accepted.

The team identified and discussed hazards that could result in such miscommunication scenarios. Many of these hazards are not unique to LAHSO, but, as will be discussed, hold short clearances may introduce additional risks.

- *Crew experience*. Several participants expressed concern over the variation in the levels of experience among pilots with respect to LAHSO communications procedures and conventions. Student pilots and non-native English speakers, for example, may be more likely to misunderstand a LAHSO clearance.

- *Coordination between approach and tower*. Participants also pointed to a lack of coordination between approach and tower controllers as a possible hazard; in particular, those cases where a LAHSO clearance is issued by tower after approach is advised that the crew is unable to hold short.

- *Flight crew coordination*. For example, errors arising because the pilot flying the aircraft is unaware that the other pilot has accepted a hold short clearance.

- *Frequency congestion*.

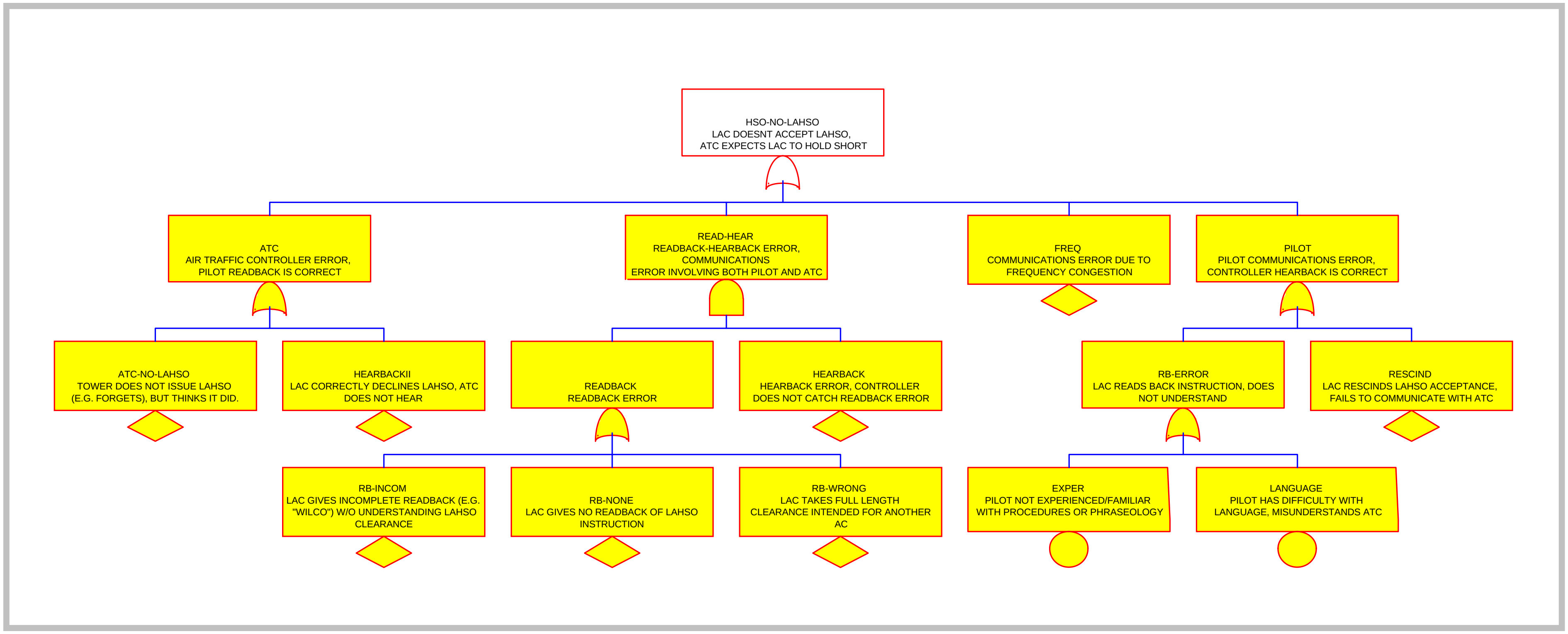
- *Split frequencies*. Errors that arise because the LAHSO aircraft and the full-length aircraft are communicating with tower on different frequencies.

- *Combined local/ground air traffic control positions*.

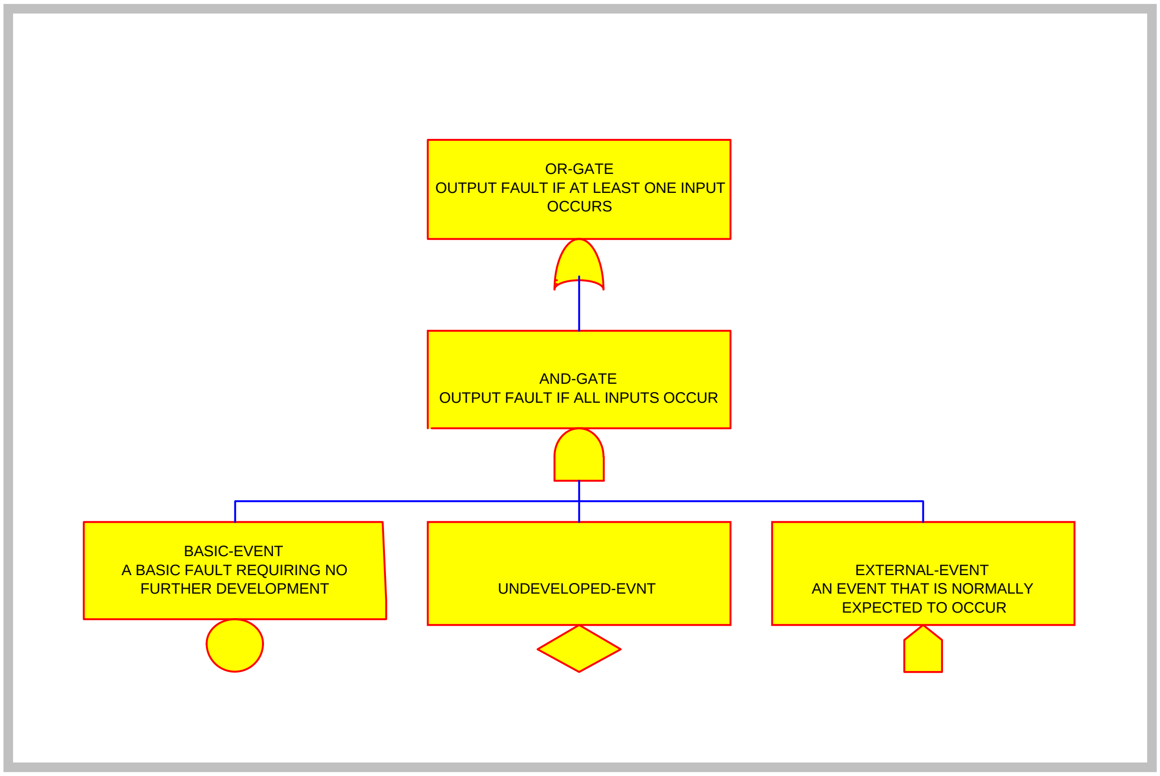
- *Readback/hearback error*.

- *Interference and bogus transmissions*.

Figure V.3.—Communications Error Fault Tree



Key to Figure V.3



D. Residual Risks

1. FAA-Industry Team Assessment of Risks

Figure V.4.—Subjective Assessment of Communications-Error Collision Risk

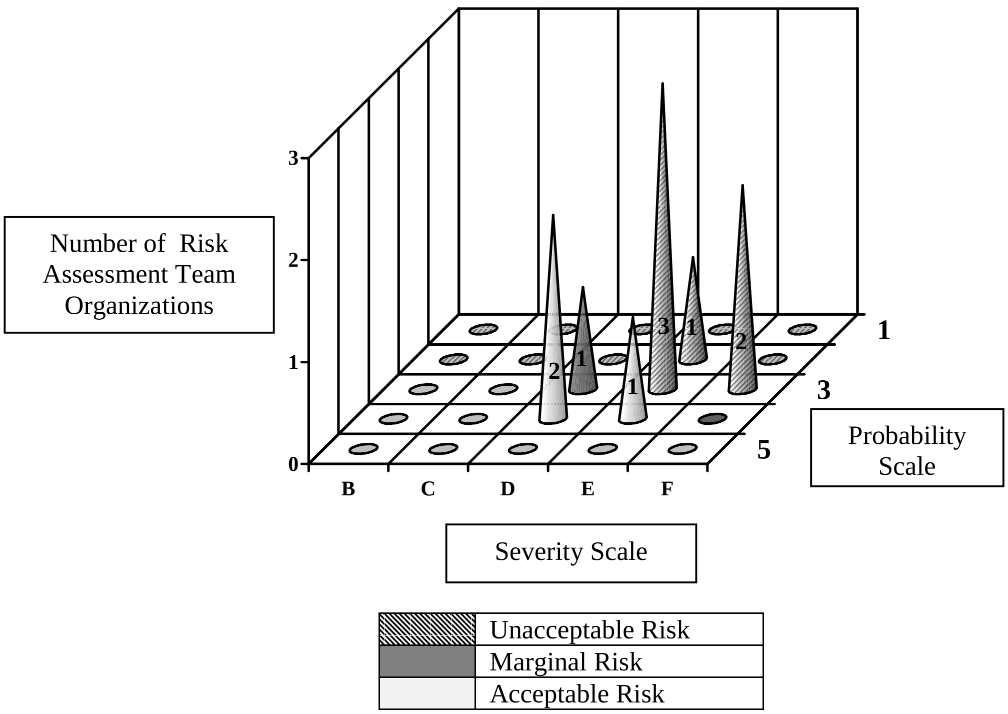


Figure V.4 graphically illustrates the FAA-industry team's assessment of the risks of a communications error induced hold short overrun and collision. Severity levels (B through F) and probability levels (1 through 5) are as defined in Section III.A.3, Table III.2. The height of each cone corresponds to the number of organizations on the team that voted for a particular severity-likelihood combination (for example, three organizations rated the risk as E3).

Generally, the team agreed that communication error is a significant risk factor, and many members concluded during the working sessions that it is not acceptably controlled. Frequency congestion, in particular, was cited as a major concern. In addition, one participant stated that solo students should be required by regulation to identify themselves as such.

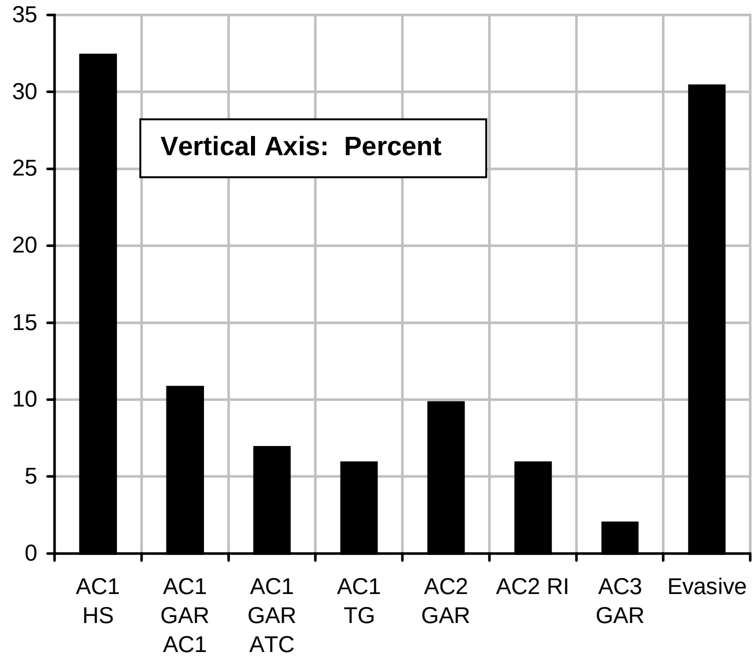
2. Statistical Information

Controller-pilot communications errors have been the subject of much scrutiny and analysis.[29] As noted above, communications issues were cited in 37% of all ASRS/NAIMS reports analyzed from the 1994-1998 period. The characteristics of ASRS/NAIMS events involving a communications error are illustrated in Figure V.5.

Over one-half of the reports involving communications errors reported a hold short point overrun or a touch and go. About 8 percent reported that the full-length aircraft executed a go around to avoid a conflict. Twenty-five percent of the reports indicated that despite an "unable" LAHSO response, traffic was observed crossing the intersection.

[29] See: Cardosi, Kim; Falzarno, Paul; Han, Sherwin, "Pilot-Controller Communications Errors: Ana Analysis of Aviation Safety Reporting System (ASRS) Reports," DOT/FAA/AR-98/17, August 1998. Wilson, Gary, "Readback/Hearback: A Key Factor in ATC Communications Between Pilots and Controllers," *Airliner*, Customer Service Division, The Boeing Company, October-December 1996, p 4. Wright, Bob, and Patten, Marcia, "Callsign Confusion," *ASRS Directline*, National Aeronautics and Space Administration (NASA), Issue Number 8, June 1996. Cardosi, Kim; Brett, Bryan; Han, Sherwin, "An Analysis of TRACON (Terminal Radar Approach Control) Controller-Pilot Voice Communications," DOT/FAA/AR-96/7, June 1996. Bürki-Cohen, Judith, "An Analysis of Tower (Ground) Controller-Pilot Voice Communications," Operator Performance and Safety Analysis Division, Volpe National Transportation System Center (VNTSC), Final Report No. DOT-VNTSC-FAA-95-41, November 1995. Bürki-Cohen, Judith, "How to Say it How Much: The Effect of Format and Complexity on Pilot Recall of Air Traffic Control Clearances, in B.G. Kanki & O.V. Prinzo (eds.) *Proceedings of Methods and Metrics of Voice Communications Workshop*, Final Report No. DOT-FAA/AM-96/10. Cardosi, Kim, "An Analysis of Tower (Local) Controller-Pilot Voice Communications, Final Report No. DOT-VNTSC-FAA-94-11, June 1994.

Figure V.5—Distribution of Characteristics for ASRS/NAIMS Events Involving Controller-Pilot Miscommunication, 1994-1998



Notes for Figure V.5:

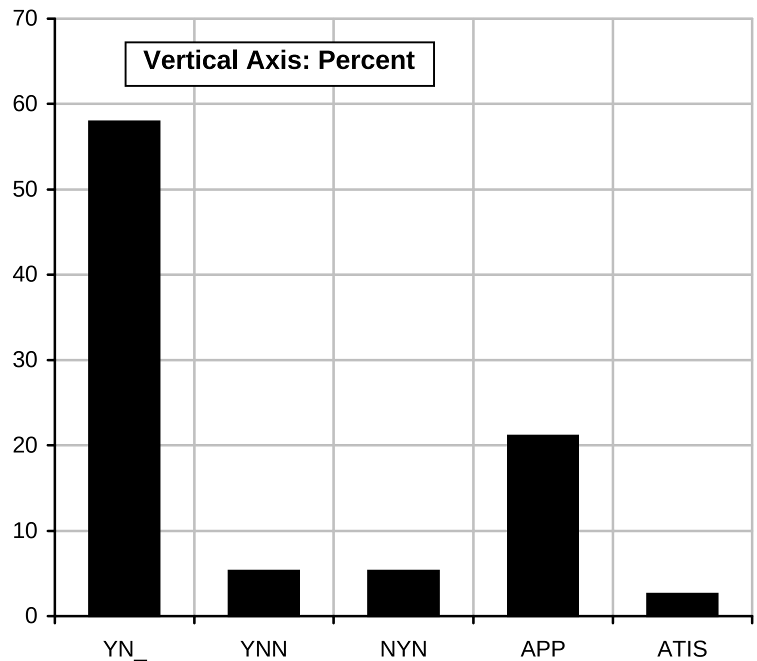
1. AC1-HS—LAHSO aircraft overruns the hold short point.
2. AC1-GAR-AC1—LAHSO aircraft goes-around (pilot initiated).
3. AC1-GAR-ATC—LAHSO aircraft goes around (air traffic initiated)
4. AC1-TG—LAHSO aircraft executes a “touch-and-go”
5. AC2 GAR—Full-length traffic goes around
6. AC2 RI—Full-length traffic goes through the intersection even though the LAHSO aircraft did not accept a hold short clearance.
7. AC3 GAR—A third aircraft (not the LAHSO aircraft or the intersecting traffic) goes around.
8. Evasive—A pilot reports having to make an evasive maneuver in order to avoid a perceived potential collision threat.

The following discussions examine, in detail, statistical information regarding communications errors with respect to each of the three accident scenarios identified in Section V.A; namely: 1) controller-LAHSO aircraft miscommunication leading to a hold short overrun, 2) controller-full-length aircraft miscommunication leading to a single aircraft event, and 3) controller-full-length aircraft miscommunication leading to a collision on the LAHSO runway.

i. Collision Due to Controller-LAHSO Aircraft Miscommunication

ASRS/NAIMS data indicate that most communications errors involved the controller and the LAHSO aircraft (again, these data should be considered in the context of the caveats enumerated earlier). Following the event tree logic, these types of errors are coded as "YN" meaning that the controller believes that LAHSO is "on" ("Y" = yes); and the LAHSO aircraft crew believes that LAHSO is "not on" ("N" = no). Figure V.6 illustrates the distribution of LAHSO miscommunications reports by event tree error types. Figure V.7 shows the the "causes" of communications errors for "YN" events.

Figure V.6.—ASRS/NAIMS Events by Type of Communication Error, 1994-1998



Notes for Figure V.6:

1. YN—Air traffic control believes LAHSO is on ("yes"); LAHSO aircraft does not believe LAHSO is on; full-length aircraft is either yes or no).
2. YNN—These events are a subset of "YN" events. Air traffic believes LAHSO is on; both aircraft believe LAHSO is not on (e.g., aircraft are landing on intersecting runways; neither has a hold short instruction).
3. NYN—Air traffic control and the full-length aircraft believe LAHSO is not on; LAHSO aircraft believes LAHSO is on (and holds short)
4. APP—LAHSO aircraft reports to approach control "unable LAHSO;" aircraft receives hold short clearance anyway.
5. ATIS—LAHSO advisory not on ATIS.

Estimating the rate of LAHSO communications errors is problematic. Based on an analysis of 11,234 controller (tower) to pilot transmissions, Cardosi estimated a pilot readback error of "less than one percent" with controllers failing to detect the readback error about "37% of the time; less than one-tenth of one percent of the total number of controller messages."[30] Based on a survey of 504 ASRS reports, Cardosi, Falzarrano, and Han constructed the distribution of miscommunication contributing factors shown in Figure V.8.[31]

Similar results have been obtained in other studies. For example, in a survey of readback/hearback errors conducted in November 1995, Seattle Center identified approximately 400 errors. During that period, the FAA-Aviation Policy and Plans Air Traffic database reports that the Center handled 109,828 aircraft, yielding a per-aircraft error rate of approximately 0.4%.[32] The Boeing Company's *Airliner* magazine summarizes the results:

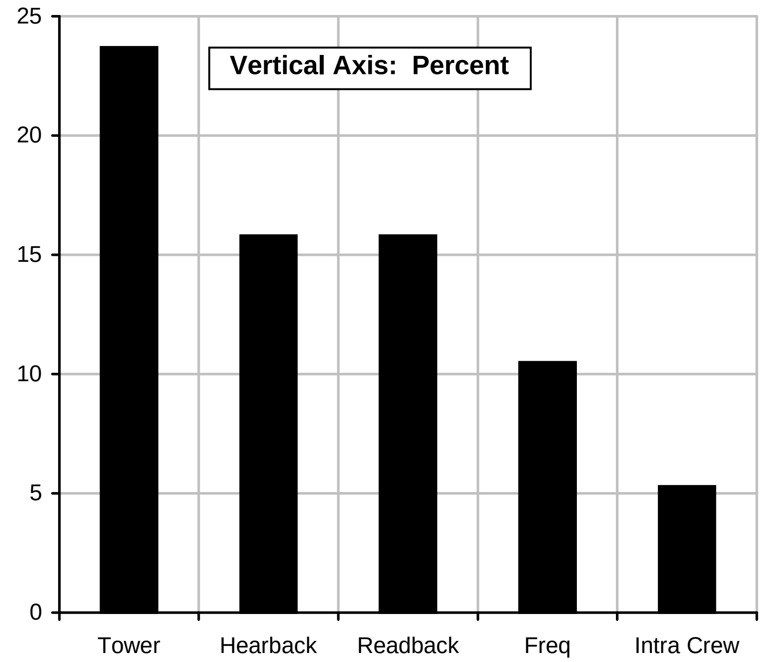
> Seattle Center conducted its study on readback/hearback errors in November 1995. Each controller was asked to note individual readback errors on a worksheet. The information was then compiled, and the data compared to other previous FAA studies. This comparison confirmed that readback/hearback errors were, in fact, increasing.

[30] Cardosi observes: "One of the most striking findings of this analysis was how few errors were found. A readback error rate of less than one percent is a tribute to the pilots and controllers operating in the National Airspace System. Even the most diligent and conscientious pilots and controllers can be involved in a communication error." Cardosi, "An Analysis of Tower (local)…", *op. cit.*, p 17.

[31] Cardosi, Falzarrano, Han, "Pilot-Controller Communications Errors…," *op. cit.* p 5.

[32] Source: FAA-APO. Total aircraft handled by Seattle Center was reported as 109,828 (total VFR: 4,374). This total represents: "The number of ARTCC en route IFR departures multiplied by two, plus the number of en route IFR overs. Thie formula assumes that the number of departures (acceptances, extensions, and organizations of IFR flight plans) is equal to the number of arrivals (IFR flight plans closed)." An "IFR departure" is an en route IFR flight which originates in an ARTCC area and enters that center's airspace. An "IFR over" is an en route IFR flight that originates outside the ARTCC area and passes through the area without landing.

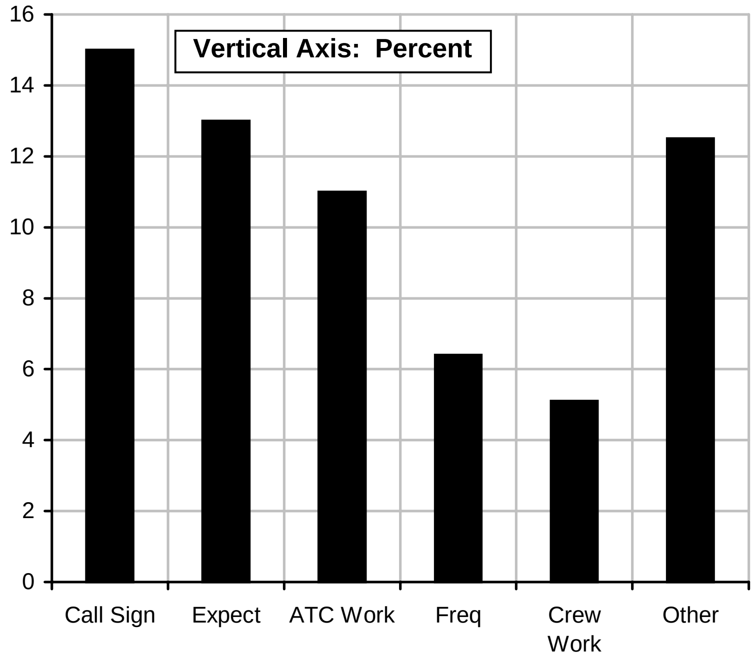
Figure V.7.—Distribution of ASRS/NAIM "YN" Communications Errors by Cause, 1994-1998



Notes for Figure V.7:

1. Tower—Reporter claims that tower did not issue a LAHSO clearance, but subsequently cleared traffic to cross the runway.
2. Hearback—Hearback error.
3. Readback—Readback error.
4. Freq—Frequency congestion reported.
5. Intra Crew—One pilot accepts hold short clearance; fails to inform pilot flying the aircraft.
6. Causes are not mutually exclusive. For example, readback/hearback errors may be due to frequency congestion.

Figure V.8.—Communications Errors Contributing Factors (Cardosi, *et. al*.) [33]



Notes for Figure V.8:

1. Call Sign—Similar call signs contribute to the communications error.
2. Expect—Pilot expectation contributes to the communications error.
3. ATC Work—Air traffic controller workload contributes to the communications error.
4. Freq—Frequency congestion contributes to the communications error.
5. Crew Work—Aircraft crew workload contributes to the communications error
6. Other—All other contributory factors.

A November 1998 event at Charlotte is an example a LAHSO readback/hearback error in which the LAHSO aircraft mistakenly accepted a full-length clearance for another (company) aircraft. Neither the LAHSO aircraft flight crew, nor the intended company aircraft crew, nor the controller detected the error, which resulted in a hold short overrun and conflict with a departing airliner.

Pilots participating in the LAHSO risk assessment were asked to give their views on undetected communications error rates. Some stated that, in their experience, error rates could be much higher than 1/1000; perhaps as much as 5%. A participating air traffic controller, however, pointed out that in many cases, controllers detect errors and take corrective action in such a way that a flight crew may not be aware the error was detected immediately.

ii. Controller-Full-length Aircraft Crew Miscommunication

The FAA team identified two miscommunication accident scenarios involving the full-length traffic: in one case, aircraft 2 is not informed of the LAHSO; in the other case, aircraft 2 lands

[33] Cardosi, Falzarrano, Han, "Pilot-Controller Communications Errors…," *op. cit*., p 5.

on the wrong runway (e.g., the wrong parallel runway). Neither accident scenario is represented in the ASRS/NAIMS database. There are two cases where aircraft were simultaneously cleared to land on intersecting runways and neither aircraft was given a hold short restriction. However, there are no examples where the LAHSO aircraft and controller states are the same (e.g., YY or NN), and the aircraft 2 state is different.

In contrast to the ASRS/NAIMS data, Cardosi's analysis of pilot-local controller communications errors shows that confusing the "right" and "left" designation for the same runway number is one of the most common types of readback errors. (See Table V.2.)

Table V.2.—Distribution of Readback Errors By Type of Information[34]

Type of Information in Error	Percent of Errors
Taxi Instructions	37%
Right/Left of Same Rwy Number	26%
Altitude	16%
Heading	10%
Transponder Code	5%
Other	5%

3. Conclusions From Expert and Statistical Data

The statistical evidence confirms the subjective appraisals of communications risks. Communication error is a factor cited in more ASRS/NAIMS LAHSO reports than any other factor including crew error. This has potentially serious implications. For example, in an event where pilot technique is a contributor, it may be more likely that the LAHSO aircraft crew is aware of the possibility of another aircraft at the intersection and, therefore, recovery factors (see-and-avoid, harder breaking, etc.) are more likely to be effective. (Recall that in about one-third of ASRS/NAIMS events, one or both flight crews reportedly took evasive action.) It is also possible that the LAHSO aircraft is more likely to be slowing down near the intersection. In the case of a communications error, on the other hand, the LAHSO crew may be unaware of the presence of another aircraft, and may be traveling much faster near the intersection.

The ASRS/NAIMS data suggest a much lower rate of communications errors than does Cardosi's analysis of pilot-local controller transmissions. This may reflect the fact that LAHSO instructions are less likely to be confused (e.g., Cardosi's data does indicate that error rates rise with the complexity of the instructions). On the other hand, as traffic (both aircraft and frequency use) increase, the likelihood of errors may increase. The ASRS/NAIMS data, therefore, may give an optimistic estimate relative to future error rates.

The probability of communications errors involving the full-length aircraft must also be considered. Although the ASRS/NAIMS data do not show this to be a historical risk specific to LAHSO, it does appear to be a generally occurring phenomenon. For certain types of LAHSO

[34] Cardosi, "An Analysis of Tower (Local)…", *op. cit.*, p 12.

combinations, then, it may be critical that both the active *and passive* LAHSO participants have some type of crew training.

D. Suggested Risk Reduction Measures

1. Near-term controls

Improving pilot-controller communications has implications far beyond LAHSO. For example, a 1998 Mitre study concludes:

> Frequency congestion is a significant problem that has an adverse effect on ATC-pilot communications. At many busy airports, voice communications approach or exceed the radio frequency capacity, especially during periods of high traffic activity. As a result, pilots often do not have time to read back ATC instructions and clearances, and controllers are not certain whether pilots have received and understood their messages.[35]

Many of the improvements suggested here have been made elsewhere and are part of an ongoing effort by the FAA to reduce communications errors.

3. **Improved cooordination between approach and tower**. FAA-Flight Standards material requires that the pilot in command advise, upon initial contact, if a LAHSO clearance cannot be accepted. ASRS data, however, indicate that this information is not always coordinated between approach and tower. The FAA should establish procedures whereby this information is coordinated between approach and local controllers.

4. **Foreign air carrier participation in land and hold short operations**. While the risk assessment team did not have the opportunity to fully analyze the possible safety implications of foreign air carrier participation in LAHSO (since, at the time of the risk assessment working sessions, its understanding was that such operations were prohibited), it did identify foreign carrier operations as a potential hazard with respect to communications. Recently issued Flight Standards guidance material, however, lays out criteria for such operations.

The FAA should develop risk-based standards for evaluating and approving foreign air carriers for participation in LAHSO before permitting such operations as a National Policy. Issues that should be considered include (also see Section IX):

- Possible miscommunication (using emergency or non-standard phraseology) between foreign pilots and ATC during a rejected landing.
- Possible effects of lack of airport familiarity on accident/incident likelihoods.

[35] Mitre, Reports by Airport Traffic Control Tower Controllers on Airport Surface Operations: The Causes and Prevention of Runway Incursions," MTR 98W0000033, September 1998, p ES-12.

- Possible effects of LAHSO lighting configuration on foreign crew not familiar with the U.S. configuration. Also, possible safety issues concerning differing LAHSO lighting standards between countries.
- Possible effects of lack of LAHSO procedure familiarity on hold short overrun or rejected landing likelihoods.
- Variability of English skills within a given foreign carrier.

5. **Anti-stuck microphone and anti-block radio technology.** Require the use of anti-stuck microphone and anti-blocking radio technology for air traffic equipment and radio equipment in aircraft operating at ATCT where LAHSO are permitted. (See footnote 35.)

6. **Site-specific studies of radio interference.** As part of the site-specific risk assessments and on-going hazard tracking programs (see Section X), airports and air traffic should establish programs to ensure the quality and integrity of voice communications. (See footnote 35.)

7. **Pilot training: "passive" LAHSO.** LAHSO training should not be limited to operators conducting LAHSO. Pilot training material should include information on the criticality of communications errors during LAHSO. This material should address hazards associated with communications errors involving the full-length (i.e., non-LAHSO) aircraft, and emphasize the need for the intersecting aircraft to acknowledge the notification of intersecting traffic holding short.

2. Long-term controls

In the long term, technological innovations may significantly improve the accuracy of controller-pilot communications. Again, these controls are not unique to LAHSO:

8. **Non-voice communications.** The FAA should investigate the application of non-voice technologies for exchanging information between controllers and flight crews (e.g., datalink) during a land and hold short operation.

9. **Automated LAHSO light system.** As noted above, industry and the FAA are already investigating the use of an automated system of LAHSO lights. Such a system would give positive visual confirmation of voice (or datalink-type) LAHSO clearances. *However, the FAA should not commit to the implementation of an automated LAHSO light system until a Preliminary Hazard Assessment (PHA) of the system concept is completed (see Section VI).*

VI. Risks Associated with Piloting Technique

The FAA team concluded that the potential for piloting technique was a critical issue that should be studied during the FAA-industry working sessions. After communications errors, piloting technique is the most common factor cited in ASRS/NAIMS reports. The preliminary hazard list identified several types of conditions that could affect crew performance.

- Flight crew
  - Pilot inexperience
  - Crew inexperience with LAHSO procedures
  - Inadequate preflight preparation for possible LAHSO
  - Lack of familiarity with the airport
  - Poor crew communication/coordination
  - Crew busy/distracted
  - Landing technique (fast, high, long, late braking)

- Airport
  - Negative runway gradient
  - Poor conspicuity of hold short markings, signs (e.g., due to water, glare, damage, changes, fading, etc.)
  - Insufficient safety areas
  - Insufficient wind/turbulence detection equipment
  - Angle of intersection limits ability to see intersecting aircraft
  - Presence of ground hazards near runways (e.g., wildlife)
  - Multiple hold short points per runway
  - Inability to see parts of the runway from tower

- Air traffic system
  - Tower issues LAHSO "late"
  - Lack of coordination between approach and tower (e.g., "keep speed up commands)
  - Approach does not advise tower of declined LAHSO
  - Communication of airport condition to pilot
  - Noise abatement procedures

- Environmental
  - Winds
  - Wake turbulence
  - Windshear
  - Visibility

The FAA-industry team grouped these hazards under two broad types of scenarios which, although they are clearly inter-related, involved different aspects of crew performance. The first group included scenarios which involved a failure to correctly recognize the hold short point and/or the distance to the hold short point. The second included scenarios where, although the crew might have correctly identified the hold short point, there was a failure to attain the proper speed, touchdown point, etc.

A. Recognition of/Misjudging the hold short point

1. Description of Existing Controls

FAA Order 7110.199 lays out requirements for signs and markings. Specifically:

- *Visibility requirements*. A ceiling of 1,000 feet and visibility of 3 miles for non-air carriers; and a ceiling of 1,500 feet and visibility of 5 miles for air carriers unles the LAHSO runway is equipped with a PAPI or VASI, in which case limits of 1,000 feet and 3 miles shall apply. (Section 9.a.1.)

- *Markings/signage requirements*. Markings and signs shall be installed in accordance with AC 150/5340-1, Standards for Airport Markings; and AC 150/5340-18, Standards for Airport Signs Systems. (Section 9.b.)

- *LAHSO lighting requirements*. Lights are required for all LAHSO associated with a taxiway, a predetermined point, or an approach/departure path. Lights are required for runway-runway air carrier night LAHSO (lights for non-air carrier LAHSO are required after June 17, 2000). Lights are required for runway-runway air carrier day LAHSO after June 12, 2000. (Section 9.c.)

- *One hold short point per runway*. (Section 7.e.)

- *Restrictions on non-air carrier operations*. Air carrier (14 CFR part 121) aircraft shall not be issued a clearance to land or depart on a runway when a non air carrier aircraft is landing to hold short of the air carrier runway. (Section 9.m.)

- *Restrictions on solo student pilots*. (Section 9.g.)

LAHSO lighting. The February 9 agreement defined three types of LAHSO lighting configurations: 1) the current lighting configuration consisting of five, six, or seven in-pavement, pulsing white lights, 2) the improved FAA standard consisting of a minimum of six in-pavement continuously illuminated white lights at the hold short point and a minimum of six pulsing lights at an alert point 1000 feet prior to the hold short point, and 3) the “international” configuration consisting of continuously illuminated red lights at the hold short point, elevated flashing lights outboard of the runway edge at the hold short point, and pulsing white alert lights at the alert point.

Both configuration 1 and 2 would be turned on whenever the runway was available for LAHSO; during this time they would be on whether or not a particular operation was, in fact, LAHSO.

Configuration 3 would incorporate some type of automatic switching system that would turn on the lights only if a specific landing clearance required the aircraft to hold short.

2. Hazards That Could Degrade Existing Controls

i. Hazards Associated with Current FAA (one-bar) Lights

Generally, the team agreed that the lighting system improves safety by enabling the flight crew to discern the hold short point more readily and perhaps by giving pilots a frame of reference to judge deceleration. The lighting system also mitigates the hazards of poor marking visibility under certain visibility, lighting, and runway conditions.

However, two participating organizations expressed very strong reservations over any lighting system that did not automatically turn itself off during a non-LAHS operation. These organizations believed that conditioning pilots to taxi through the hold short lights is, in itself, a hazard.

ii. Hazards Associated with the Proposed FAA (two-bar) Lights

There were several concerns over the two-bar system:

- *Potential lack of coordination with foreign countries which may already employ a single bar standard*. Concerns were expressed over the fact that some foreign countries may already be employing a single bar system with the pulsing light at the hold short point. Under the proposed FAA system, the flashing bar would be located 1,000 feet prior to the hold short point. Conceivably, U.S. pilots, conditioned to taxi through the pulsing bar domestically, would be at risk to pass through the hold short point in countries using a single pulsing bar.

- Delay in exiting the runway caused by misunderstanding the meaning of the pulsing alert bar.

- Distraction to full-length aircraft crew caused by pulsing bar.

- Excessive braking caused by confusion over the pulsing bar.

- Clearance to cross the alert bar misinterpreted by the pilot as a clearance to cross both sets of lights.

- Alert lights near the intersection of a second parallel runway intersecting the LAHSO runway increasing confusion to full-length pilots as to their correct landing runway.

- Similar to one-bar issue: lights are always on if LAHSO is available.

iii. Hazards Associated With Proposed "International" Standard[36]

The hazards associated with the proposed standard are similar to those enumerated above for the FAA two-bar system. The assessment of risks associated with a hypothetical future lighting configuration is beyond the scope of this study. However, some hazards associated with an automated LAHSO light system may include:

- If the control depends on some type of voice recognition system (and assuming reliability and fidelity of the voice recognition software) what are the possible ways that misspoken clearances, readback and hearback errors can lead to false-LAHSO or false-no-LAHSO indications? How will the system respond to a lack of readback, frequency congestion, or other interference? Could this system lead to scenarios where the pilot's interpretation of controller clearances are at variance with the light indications?

- Datalink issues (e.g., can datalink respond quickly enough to changing conditions in which LAHSO clearances are accepted and then rescinded?)

- Would the hold short and alert lights be turned off simultaneously? Would they be turned off automatically only? Or, under certain conditions, by the controller? Under what criteria/logic rules would the hold short and alert lights be turned off? Only after a clearance to cross the hold short point? After the aircraft has departed the runway?

- How might LAHSO lights affect a subsequent full-length landing clearance?

- How might the activation of the lights affect an operation on the intersecting runway? (E.g., pulsing lights suddenly appearing during an arrival or a takeoff?) Particularly, if the alert lights are near or in a runway intersection.

3. Statistical Data

ASRS/NAIMS reports contain only one reference to the conspicuity of hold short markings: a general aviation pilot reported that his failure to hold short was, in part, due to poor markings.

4. Assessment of Residual Risks

The subjective assessments which follow relate to an accident scenario involving a hold short overrun and collision due to a failure of the LAHSO aircraft pilot to correctly identify/recognize the hold short point or the distance to the hold short point. Members of the FAA-industry team were asked to rate risks assuming a single-bar configuration and a two-bar (two white bars, alert bar pulsing) configuration.

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[36] At the time of this writing, ICAO has not endorsed the two-bar (red-white), automatic LAHSO light system which was described in the February 9 agreement as the "Proposed International LAHSO Lighting Configuration."

i. Current FAA (one-bar) Lights

Generally, participants of the team rated hold short overrun and collision risks assuming a single-bar system to be acceptable. (See figure VI.1)

Figure VI.1.—Subjective Assessment of Risks Associated With A Failure to Recognize the Hold Short Point: One-Bar

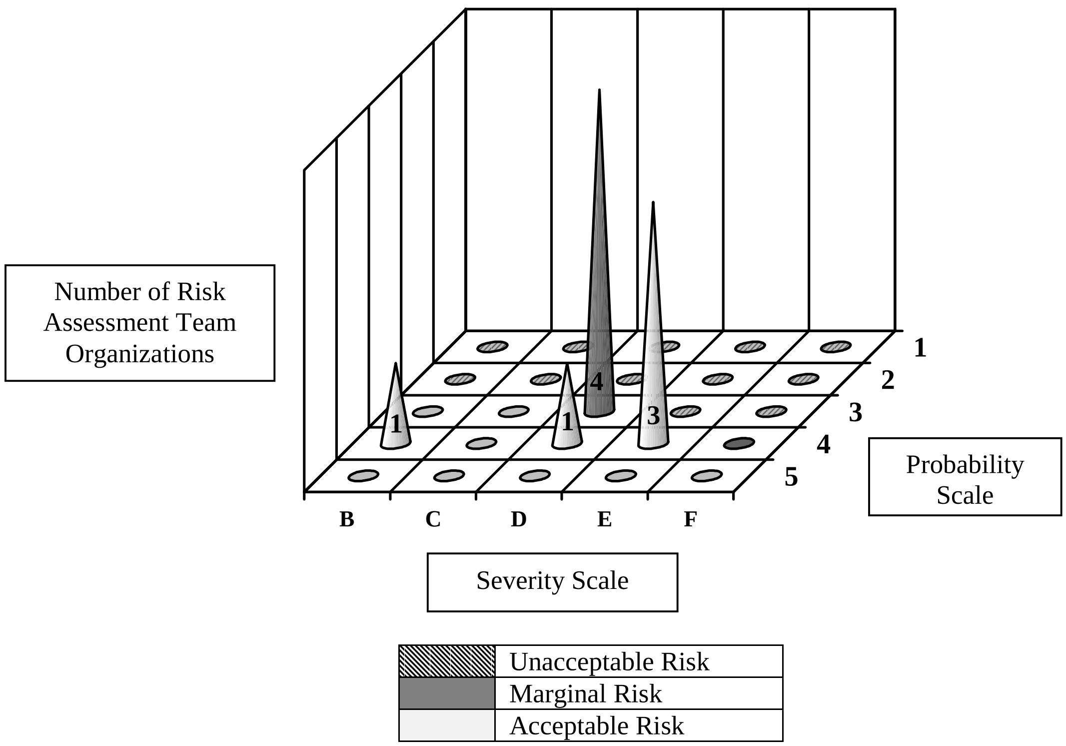
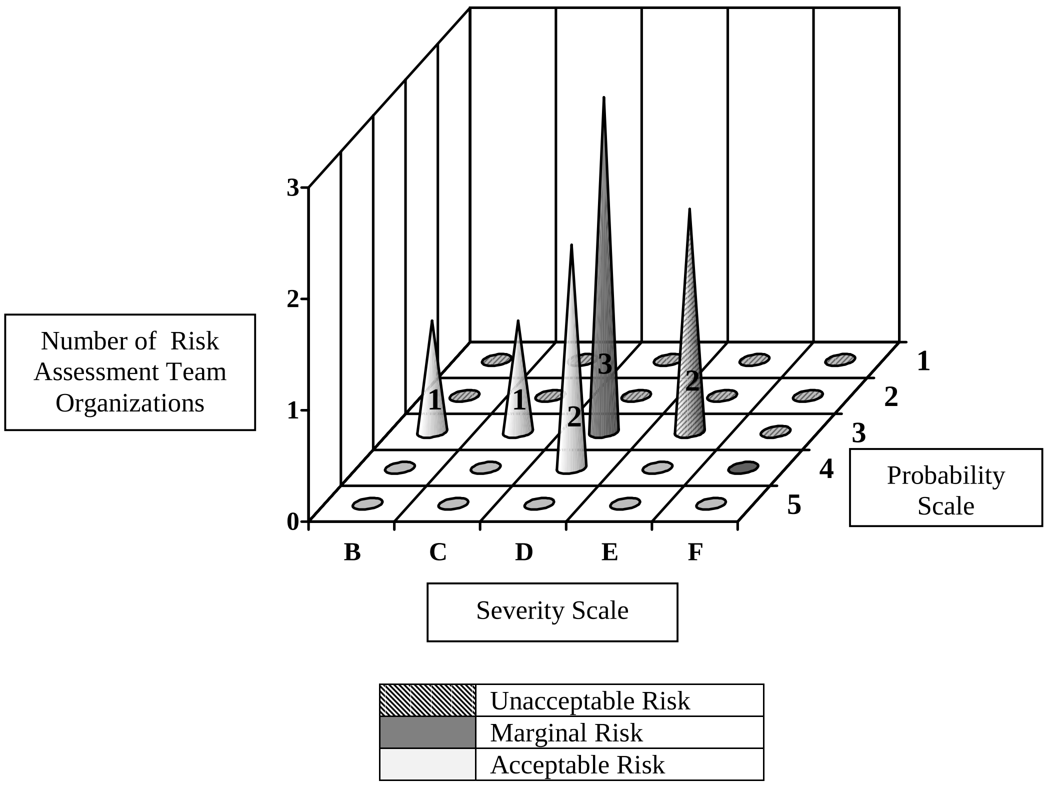


Figure VI.2.—Subjective Assessment of Risks: Two-Bar



ii. Proposed FAA (two-bar) Lights

Several participating organizations expressed reservations over the net-benefits of a two bar system. Significantly, none of the participating pilot's organizations rated the two-bar configuration as better (i.e., lower collision risk) than the one-bar; two of the groups represented rated the uncontrolled two-bar system as introducing unacceptable risks.

iii. Proposed International (two-bar) Lights

Risks for this system were not rated since the specifications for such a system have not been fully described.

5. Suggested Risk Reduction Strategies

The general team consensus was that the current FAA LAHSO light configuration, with one bar of pulsing white lights, is acceptable (with respect to the risks associated with a hold short overrun and collision as a result of failing to recognize the hold short point).

As noted earlier, however, two organizations felt that the fact that the lights were always on when the runway was available for LAHSO was a hazard since it would condition pilots to pass through the lights. One organization preferred to have no lights (and, hence, no night LAHSO) until a reliable automated lighting control system was available.

Opinion was divided on a two bar system. FAA-AAS provided video taped documentation of two sets of tests. One was performed in a computer simulator, the other was conducted by the FAA Technical Center using actual lights placed on (not in) the runway surface. In the latter testing, the lights were observed from an aircraft simulating an approach and passing over the runway (at about 50 feet), and from a truck driving down the runway. (Note: the ratings given above were conducted after the team viewed the computer simulations only. Viewing of the actual lights in the Technical Center tests showed that the computer simulation did not provide a completely accurate depiction of the lights.)

After viewing the AAS-Technical Center tests, many participants were uncertain over the net benefits of the two-bar system. Some thought that, at best, the benefits from an additional alert bar would be offset by its safety disbenefits, resulting in little or no net benefit over a single bar system. As noted above, none of the pilot's groups or FAA-Flight Standards rated the two-bar system as superior to the single-bar system—given the ranges of the risk matrix. Also it should be noted that no simulations have been performed with respect to the effects of an alert bar on an intersecting runway.

The lack of testing and analysis of the possible deleterious effects of the two-bar system is particularly troubling in light of the analysis of ASRS/NAIMS go-around events presented in Section III: approximately 12 percent of LAHSO aircraft go-arounds involved a conflict with an aircraft that was delayed in departing the runway (this hazard is discussed in greater detail below). The visual information provided by FAA-Airports does raise a concern that the two-bar system could exacerbate this problem and result in increased collision risks with intersecting traffic. In addition, as noted earlier, it is not clear whether the two-bar system might be in conflict with certain foreign countries—particularly with respect to the meaning (either "alert" or "stop") of the pulsing white light.

Suggested Risk Reduction Strategies:

10. **Do not implement the interim two-bar configuration without evaluation and testing.** Implementation of the two bar system should commence only after thorough simulation testing and evaluation to determine its effects on: 1) the likelihood of exiting delays, 2) delays for subsequent traffic and collision/conflict likelihoods, 3) intersecting traffic, and 4) the net benefits of a two-bar system over the single-bar system.

11. **Do not commit to an automated two-bar system until a thorough Preliminary Hazard Assessment (PHA), that includes simulation testing, is completed**. In principle, an automatically controlled system of LAHSO lights may mitigate many hazards including those associated with communications errors and conditioning pilots to pass through pulsing lights. However, many detailed questions must be answered before making a final commitment to automated lights. These issues include:

- Are there potential hazards associated with lights that come on or off for an operation on an intersecting runway?
- For a condition where the LAHSO aircraft is followed by a full-length arrival on the same runway, when are the lights turned off? Before the LAHSO aircraft is cleared to cross a hold short runway. After?
- For a condition where a full-length arrival is followed by a LAHSO arrival on the same runway, when are the lights turned on? While the first aircraft is still on the runway? After it has cleared?
- Will the lights be automatically turned on and off, or on only?
- Will the algorithm that governs on/off states be the same for all airports? Are there airport or runway configuration specific issues that will require different algorithms for different sites?
- Will the on/off algorithm require that the system know the position of all aircraft?
- If algorithms are different for different airports. Could the conditions under which the lights are turned on or off be different for different airports? Is this a hazard?
- Could there be different algorithms for different runway combinations at the same airport? Is this a hazard?

B. Landing Technique

A second class of accident scenarios related to flight crew performance involves landing technique: e.g., unstabilized approach, excessive speed, landing long, etc. Selected ERC data relating to piloting skill are shown in Table VI.1. As noted above, errors in landing technique often are the culmination of an amalgam of exogenous factors such as the airport/runway configuration and environment conditions.

1. Description of Existing Controls

Controls relating to the pilot.

- *Foreign operators*. Foreign air carrier and foreign commuter operations are not to be issued LAHSO clearances. (FAA Notice 7110.199, Section 7.h.)

- *Non-air carrier LAHSO*. Air Carrier aircraft shall not land or depart on a runway when a non-air carrier aircraft is landing to hold short of the air carrier runway. (FAA Notice 7110.199, Section 7.i.)

- *Solo student*. If a pilot identifies himself as a solo student, that pilot shall only be offered a LAHSO clearance for dry-day runway/runway. (FAA Notice 7110.199, Section 9.g.)

- *Training*. Before an operator can conduct LAHSO, training for the flight crewmembers must be instituted. (*Flight Standards Handbook Bulletin for Air*

Transportation, HBAT 99-04A, *Flight Standards Information Bulletin for General Aviation*, FSGA 99-02A and FSGA-99-08.)

- *Available Landing Distances (ALD).*

- *Pilot pre-planning*. The pilot in command shall become familiar with all information concerning runway lengths. (*Flight Standards Handbook Bulletin for Air Transportation*, HBAT 99-04A, *Flight Standards Information Bulletin for General Aviation*, FSGA 99-02A and FSGA-99-08.)

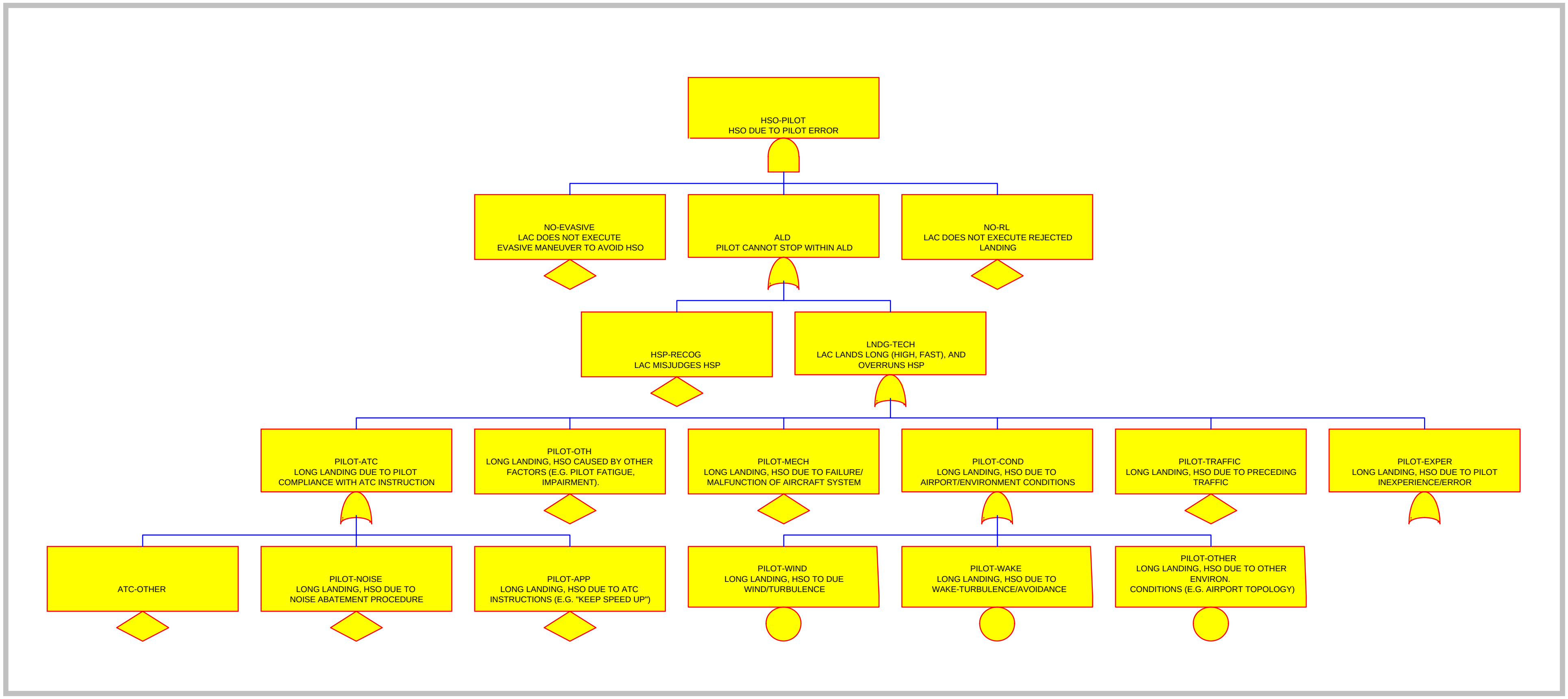
- *ATIS announcement*. An announcement will be made on the ATIS when LAHSO is expected to be in effect. (FAA Notice 7110.199, Section 9.h.)

- *Inflight planning*. Pilot shall determine the capability for a land and hold short clearance as soon as possible after notification of LAHSO. (*Flight Standards Handbook Bulletin for Air Transportation*, HBAT 99-04A, *Flight Standards Information Bulletin for General Aviation*, FSGA 99-02A and FSGA-99-08.)

- *Authority to decline a LAHSO*. The pilot in command has the final authority to accept or decline any land and hold short clearance. (*Flight Standards Handbook Bulletin for Air Transportation*, HBAT 99-04A, *Flight Standards Information Bulletin for General Aviation*, FSGA 99-02A and FSGA-99-08.)

- *Rejected Landing Procedures*. Criteria for rejected landing procedures must be published in advance. A rejected landing must be initiated within the first one-third of the available landing distance, but in no case greater than 3,000 feet down the runway, whichever is less. (*Flight Standards Handbook Bulletin for Air Transportation*, HBAT 99-04A, *Flight Standards Information Bulletin for General Aviation*, FSGA 99-02A and FSGA-99-08.)

Figure VI.3.—Pilot Error Fault Tree



Key for Figure VI.3

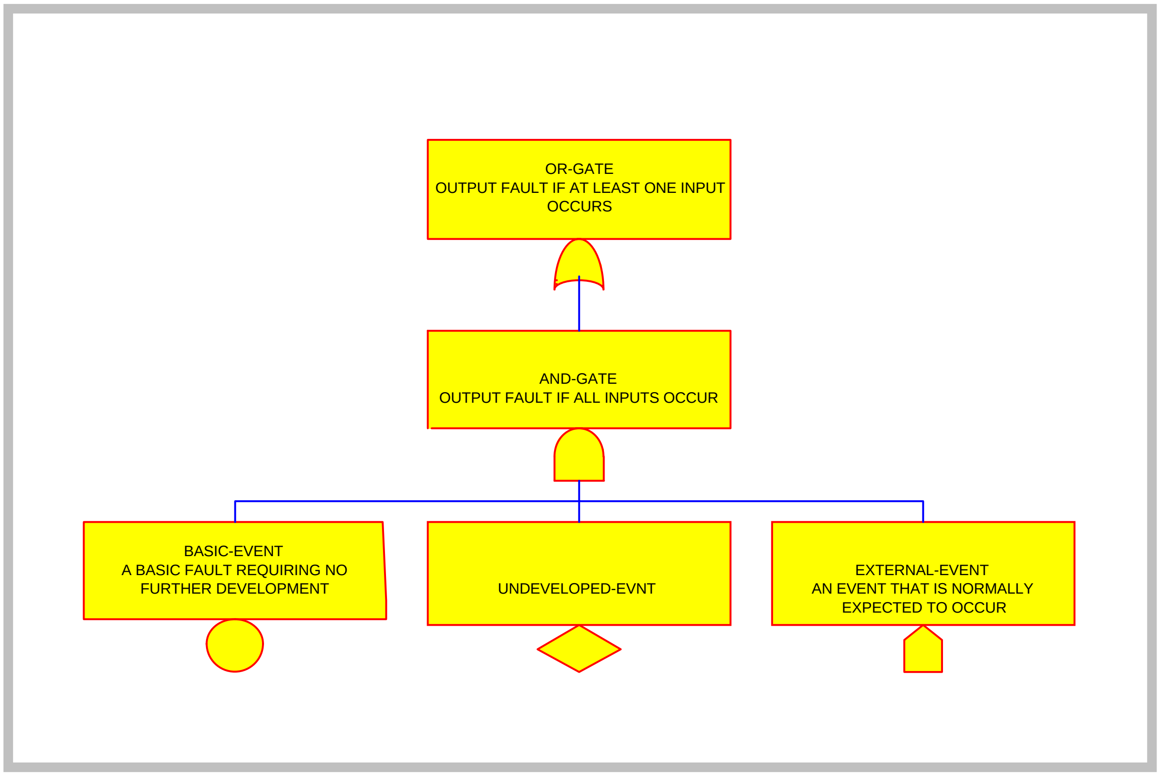


Table VI.1.—FAA LAHSO ERC Selected Data Regarding Piloting Skill

Primary Hazard	Contributors	Selected Events
Inadvertent overshoot of hold short point due to pilot lack of knowledge/skill.	Less than adequate training. Less than adequate standards	*HOU Pilot Deviation*. Landing Grumman AA-5 fails to hold short and departing B-737 aborts takeoff. *SBA ASRS 361150*. IFR training flight with instructor and pilot under hood on ILS with LAHSO clearance. Student's hood removed at 100' AGL, too far down the runway to stop. *BUR ASRS 405615*. General Aviation aircraft unable to hold short. May not have acknowledged LAHSO. Air Carrier at taxi speed at intersection. *PWM ASRS 383107*. General aviation aircraft failed to stop prior to hold short point, but not runway. B-737 on full-length runway had already turned off. *PNE ASRS 376959.* Aircraft porpoises on landing and goes-around with departing traffic. Must bank to miss traffic (NMAC). PNE ASRS 376770. PA-28 goes-around and must bank steeply to miss departing PA-31. (NMAC). BUR ASRS 370383. PA-32 is high and fast on landing goes past hold short point but not runway. Tie at intersecting runway as both aircraft stop. BUR ASRS 375210. Single engine aircraft goes-around and misses commuter on departure. (NMAC).

Controls relating to environmental conditions that might affect pilot performance.

- *Tailwind*. The tailwind on the hold short runway shall be calm (FAA Notice 7110.199, Section 9.a.3.)

- *Wind shear*. LAHSO shall not be utilized if wind shear advisories are included in the ATIS broadcast. At locations not served by an ATIS, or where the ATIS is out of service, there cannot have been any reports of windshear for 20 minutes prior to the issuance of a LAHSO clearance. (FAA Notice 7110.199, Section 7.f)

- *Weather minimums*. Non-air carriers—ceiling 1,000 feet and visibility 3 miles. Air carriers—ceiling 1,500 feet and visibility 5 miles unless the LAHSO runway is equipped with a PAPI or VASI in which case 1,000 feet ceiling and 3 miles visibility shall be applicable. (FAA Notice 7110.199, Section 7.f)

- *Other hazardous conditions*. LAHSO shall be terminated for any situation which, in the judgment of the tower supervisor/controller-in-charge, would adversely affect land and hold short operations. (FAA Notice 7110.199, Section 9.h.)

Controls relating to aircraft systems.

- *Minimum Equipment List (MEL)*. LAHSO is prohibited if the aircraft is subject to any MEL item that affects the stopping capability of the aircraft.

Controls relating to the airport.

- *Vertical guidance*. Air Carrier LAHSO is not authorized on a runway that does not have electronic or visual vertical guidance. (FAA Notice 7110.199, Section 9.d.1.)

2. Hazards That Could Degrade Existing Controls

The FAA-industry team identified and discussed several ways in which the existing controls could be degraded. These are illustrated in Figure VI.3.—Pilot Error Fault Tree. These included: 1) wind conditions including windshear, 2) piloting procedure (e.g., the potential that the autoland system may induce a long landing), 3) air traffic coordination (e.g., approach instruction to “keep speed up”), 4) conflict with preceding traffic (traffic slow to depart the runway), 5) wake turbulence avoidance, 6) mechanical problems, 7) airport topology (e.g., variable threshold crossing heights at different runways).

i. Wind Conditions

Approximately 9 percent of the ASRS/NAIMS LAHSO events for the period 1994-1998 reported wind conditions as a contributing factor. Sample wind/turbulence event data submitted to the FAA ERC is shown in Table VI.2. The FAA-industry team discussed several possible failure paths relating to existing controls for wind:

- Wind measuring equipment not functioning properly

- Lack of standardized wind measuring equipment for LAHSO airports which may result in inconsistent measurements/reporting.

- Wind indicating instrument may not be located so as to give accurate information relating to LAHSO runway.

- Procedures may not provide timely information, especially with respect to transitioning conditions.

The lack of standardized wind measuring equipment was of particular concern to some participants. Automated surface observation system (ASOS) reports, for example, are averages.

The low level windshear alert system phase 2 (LLWAS-2) uses six anemometers located around the airport to measure and report sector-oriented wind direction, speed and gusts.[37] The LLWAS-NE (network expansion) and –RS (Relocation/Sustainment), which use networks of up to 32 anemometers, can provide wind information for a specific runway. In addition, some aircraft may be equipped with cockpit wind indicators.

Table VI.2.—Selected FAA LAHSO Event Review Team Data Regarding Wind/Turbulence Condition Risks

Primary Hazard	Contributors	Selected Events
LAHSO clearances during inappropriate weather conditions: tailwinds, crosswinds, rain, low level windshear alerts.	Adverse weather conditions develop quickly.	*ARS 404476*, *404474*, *404475*. B-727 exceeds hold short limit in gusty crosswind with air carrier landing Rwy 32L. Landing air carrier must go-around. *ASRS 382294*. SF-340 goes through hold short point but not runway due to being heavy, fast and crosswind conditions. *ASRS 369184*. B-737 unable to hold short due to low level windshear alert, high speed for noise profile descent, goes past intersection with B-747 on takeoff roll. B-747 aborted and blew tires. *ASRS 411438*. MD-80 pilot indicates LAHSO is ongoing with tailwind of 6-8 knots *ASRS 411438*. ATC conducts LAHSO operations with tailwind to Rwy 18R. Wind 010/6 to 350/8. *ASRS 412164*. ATC conducts LAHSO operations with tailwind to Rwy 31. Wind 100/11G20, with LLWAS Alerts.

Changing conditions were also a concern to some participants. Pilot reports of changing wind conditions, for example, would not necessarily result in immediate action from air traffic, for example. Rather, it is likely that a controller would seek confirmation from another aircraft or from other sources. One participant was concerned that the requirement in Notice 7110.199 Section 9.A.4 would not provide sufficient margins against windshear risks. The participant suggested amending 7110.199 to including a provision to terminate LAHSO "when windshear is anticipated," for example when there are thunderstorms in the area.

[37] LLWAS collects information from remote stations, and processes the data using windshear, microburst and gust algorithms to provide air traffic control with wind speed and wind direction, the severity and type of wind events as they relate to a specific runway (LLWAS-NE –network expansion and LLWAS-RS) or airport sector (LLWAS-2). Center field wind speed and direction and gust speed are reported to the TRACON (terminal radar control). LLWAS-RS provides windshear, microburst and center field wind information to several different displays located around the airport. Typically, the master station controller and master station radio are located in an equipment room in or near the control tower. The LLWAS-2 configuration is operating at 101 airports.

ii. Pilot Experience

Based on a general observation that error rates may be related to experience levels, one participant suggested that experience requirements for LAHSO be stipulated in Federal Aviation Regulations. The FAA-AIDS/NTSB overrun data and the ASRS/NAIMS event data, however, do not indicate a clear statistical link between pilot experience and the likelihood of a landing overrun or hold short overrun. In part this is due to the multiplicity of factors which are typically involved in such accidents/incidents. Figures VI.5 and VI.6 show the distribution of landing overrun accidents/incidents (which include NTSB, FAA-AIDS, and NAIMS data) by the experience of the pilot measured in terms of total flight hours and flight hours in the make/model of the accident/incident aircraft.

Extreme care is required in interpreting these data. For example, while Figure VI.6 shows a high number of accidents/incidents in the 0-1,000 make/model flight hour range for part 135, this could be a function of the number of pilots who fall in that category and may *not* say anything about the probability of an accident for a part 135 pilot in that category. Research is required to determine how pilot experience affects overrun accident/incident likelihoods. It may be that lack of familiarity with the airport or landing runway are factors which should also be considered.

Figure VI.5.—Landing Overrun Accidents/Incidents by Pilot Experience (Total Flight Hours), 1994-1998

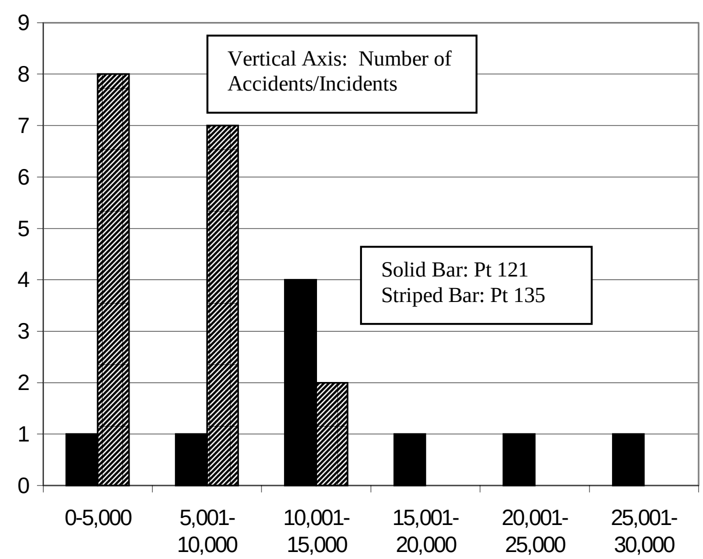
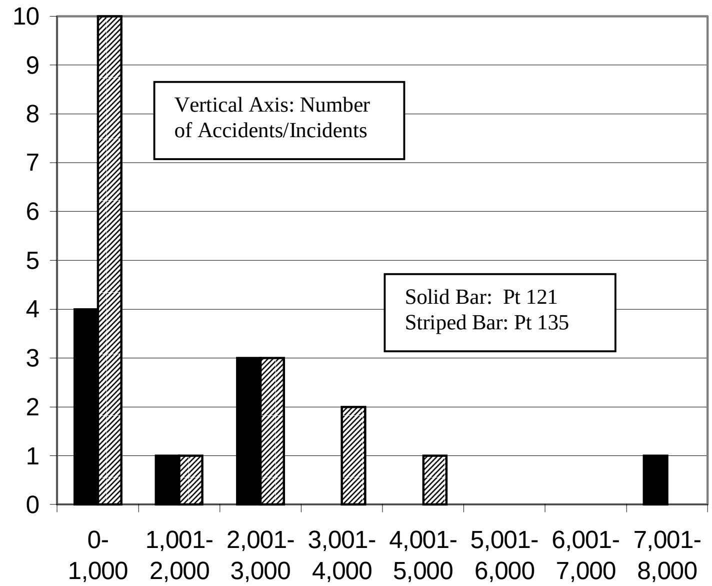


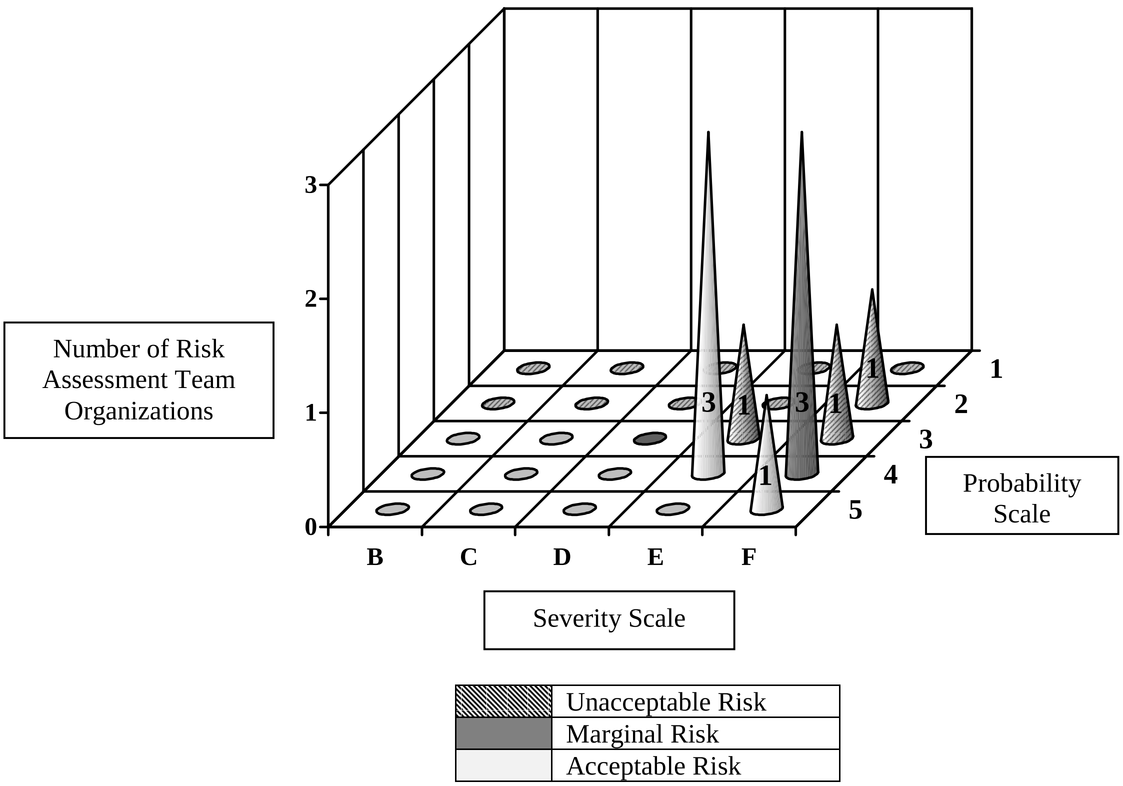
Figure VI.6.—Landing Overrun Accidents/Incidents by Pilot Experience (Make/Model Flight Hours), 1994-1998



3. Residual Risks

i. FAA-Industry Team Assessment of Risks

Figure VI.7.—Subjective Assessment of Hold Short Overrun and Collision Risk: Pilot Technique



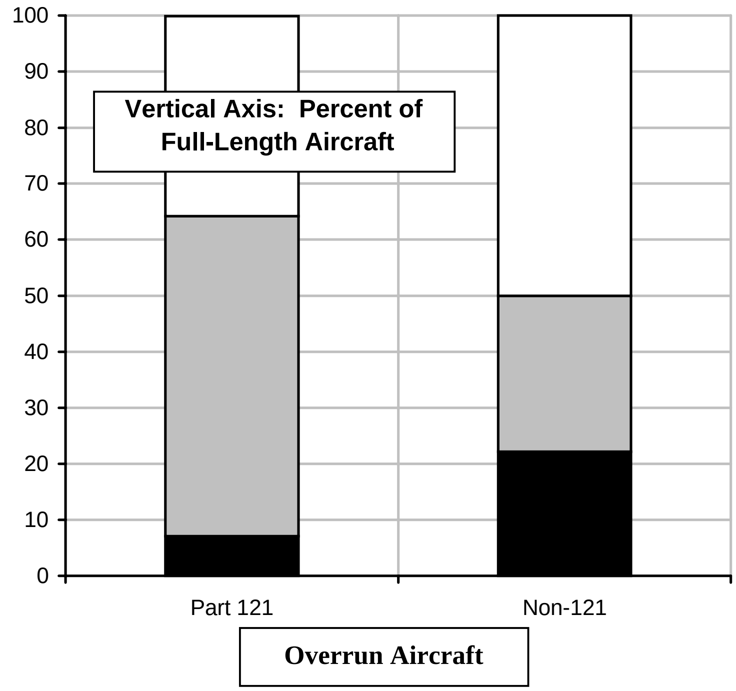
iii. Statistical data

Several members of the FAA-industry team expressed doubts over how effective existing measures will be in controlling the risks associated with piloting error. Approximately 87% of general aviation ASRS/NAIMS hold short overruns and approximately 61% of air carrier ASRS/NAIMS hold short overruns reportedly involved some type of piloting error. Figure VI.8 shows the distribution of intersecting traffic for part 121 and non-part 121 operators.

4. Suggested Risk Reduction Strategies

Several comments were received regarding possible additional controls relating to pilot performance. One participant expressed concerns that major changes to existing regulations will reduce safety since pilots and controllers will not necessarily be familiar with the latest information. Two participants felt that the existing system of requirements is becoming too encumbered such that participants—pilots, controllers, airports—are lacking an "understanding of current roles and responsibilities."

Figure VI.8.—Distribution of Intersecting Traffic Operator Types For Part 121 and Non-Part 121 Overrun Events, 1994-1998



Key:	Full-Length Aircraft Type
(white)	Operator Unknown
(gray)	Part 121 Operator
(black)	Non-Part 121 Operator

In recognition of the above, FAA-Flight Standards and Air Traffic have established more explicit guidelines regarding: 1) who can participate in LAHSO (i.e., air carrier versus non-air carrier types of operations permitted), 2) the ultimate authority to reject a hold short clearance, and 3) the criteria under which a LAHSO aircraft should initiate a rejected landing. These policies can be improved in several ways:

12. **Minimize the likelihood of go-arounds as a result of declined LAHSO clearances.** It is clear that a critical hazard control in the LAHSO procedure is the pilot's knowledge of her/his aircraft state, personal condition, and comfort with a hold short operation. Team discussions and ASRS data, however, indicate that under some conditions pilots perceive that an "unable" response to a LAHSO clearance will result in a "punitive" go-around. It is not clear whether these cases are in fact punitive or simply the result of aircraft separation requirements that

would not have permitted a full-length clearance. A representative from air traffic indicated that "punitive" go-arounds are not consistent with official policy and that at least one facility has been reminded of this. Whether or not they are punitive, go-arounds reduce the effectiveness of existing controls in that they may induce some pilots to accept landing risks that they would not otherwise take. Two measures to reduce the likelihood of go-arounds are:

- Issue system-wide clarification of LAHSO policy regarding go-arounds issued after a rejected LAHSO clearance.
- Improve coordination between approach and local controllers to minimize the likelihood of go-arounds—particularly after approach has been notified that an arrival is unable to hold short.

13. **Foreign air carrier participation in land and hold short operations**. The FAA should develop risk-based standards for evaluating and approving foreign air carriers for participation in land and hold short operations. (See Section VI.)

14. **Establish rejected landing procedures**. Guidance material from Flight Standards places emphasis on the importance of attaining an appropriate touchdown point. If this is not accomplished, the guidelines require a rejected landing. Thus, a "control" for the hold short overrun collision risk, is to transfer part of this risk to rejected landings. The effectiveness of this requirement to reduce the risks of a hold short overrun, then, depends on the degree to which safeguards are established for rejected landing procedures. In other words, the effectiveness of a requirement to execute a rejected landing is lessened if pilots perceive the subjective risks associated with a rejected landing to be greater than the risks associated with a hold short overrun. (See next Section).

Other suggested risk reduction strategies included:

15. **Experience.** Accident and incident data suggest a link between pilot experience and the likelihood that the hold short point will be overrun. The FAA should evaluate the need for establishing LAHSO experience requirements, including: 1) flight hours, 2) flight hours in type, 3) familiarity with airport/runway.

VII. Risks Associated With Rejected Landings

Of the 11 reports of pilot initiated go-arounds in the ASRS/NAIMS database (1994-1998), eight were initiated by a pilot flying under 14 CFR part 91, and three by a pilot under part 121. All six touch-and-goes were executed by pilots under part 91. There were no pilot initiated go-arounds or touch-and-goes reported under part 135 or part 125. A summary of selected ERC data relating to rejected landings is shown in Table VII.1.

Table VII.1.—Selected FAA LAHSO ERC Data Regarding Rejected Landings

Primary Hazard	Contributors	Selected Events
Inability to successfully separate traffic in the event of a balked landing.	Airport configuration, aircraft type, aircraft performance. Clearance distance minimized at intersection.	*MIA ASRS 413615*. Preceding aircraft prior to LAHSO aircraft is slow in clearing runway, B-737 cleared for takeoff on intersecting runway when LAHSO aircraft goes-around and must take evasive action. (NMAC) *LAS ASRS 385990*. B-737 makes short Takeoff due light load and passes over A-320 doing Go-around after A-320 unable to Hold Short. Two tower frequencies in use. (NMAC) *PNE ASRS 376959*. Aircraft porpoises on landing and goes-around with departing traffic. Must bank to miss traffic (NMAC). *PNE ASRS 376770*. PA-28 goes-around and must bank steeply to miss departing PA-31. (NMAC). *BUR ASRS 375210*. Single engine aircraft goes-around and misses commuter on departure. (NMAC). *LAS ASRS 392905*. General concern – Lack of guidance and information regarding go-arounds. Pilot is concerned that go-arounds are punitive for LAHSO refusal.

A. Summary of FAA-Industry Team Findings

On a historical basis, pilot initiated go-arounds occur with much less frequency than hold short overruns (the difference decreases when one includes touch-and-go landings initiated after a hold short clearance). Yet, this issue has generated the most profound differences in the discussions over LAHSO policy. To a large degree these differences reflect: 1) genuine differences in the perceived risks associated with rejected landings, and 2) concerns over the responsibility for safely executing the procedure.

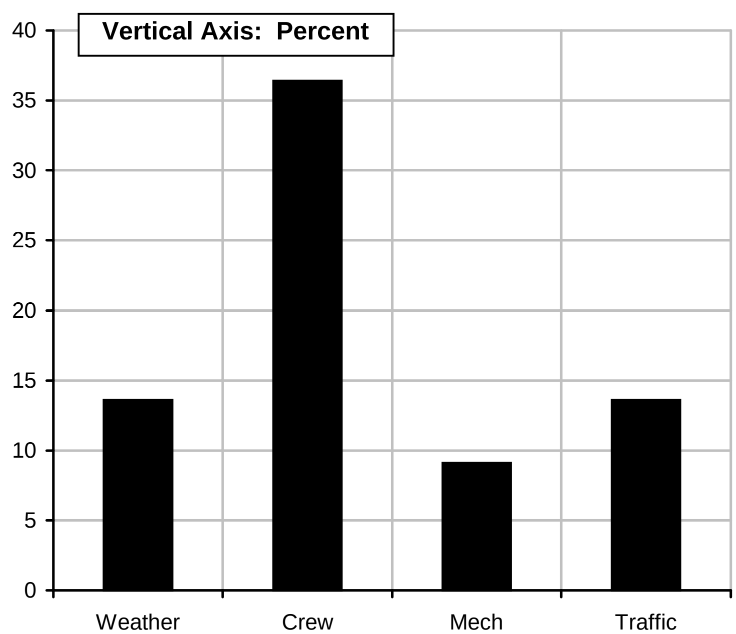
1. Differences in risk perceptions.

A mid-air collision over an airport—or even a loss of control due to evasive maneuvering to avoid a collision—is perhaps the most horrific accident scenario associated with LAHSO. In this context, one can understand the position that the absence of explicit procedures governing a rejected LAHSO landing is problematic—no matter how unlikely a mid-air collision from a probabilistic or geometric point of view.

Some participants also raised the question of whether LAHSO itself may increase the likelihood of go-arounds. This follows for two reasons: 1) increased traffic (see projections of future LAHSO activity in Section III) may increase the likelihood of conflicts between in-trail aircraft, and 2) new procedures may require increased use of rejected landings.

Increased traffic leading to conflicts between in-trail aircraft. Figure VII.1 shows the distribution of ASRS/NAIMS LAHSO go-arounds (not including LAHSO aircraft touch-and-goes) by contributing factor. The potential for increased go-arounds can be illustrated in several scenarios:

Figure VII.1.—Distribution of ASRS/NAIMS Go-Arounds
By Causal Factor, 1994-1998



Notes:

1. Weather—Environmental conditions including rain, wind.
2. Crew—Crew go-around due to excessive speed, long landing, etc.
3. Mech—Indication of mechanical problem (e.g., no gear light) causes pilot to go-around.
4. Traffic—Conflict with traffic on the runway causes pilot to go around.

- *Go-around initiated by a full-length arrival due to miscommunication between the controller and a full-length departure in position and holding.* In this case, LAHSO creates a go-around scenario in which a departure is delayed due to uncertainty that traffic will hold short of her/his runway; her/his delay, in turn, forces an arrival to the full-length runway to go-around. In one example (Chicago, 1994), the reporter (in position and holding on 9L) heard the LAHSO aircraft (instructed to land on 14L and hold short of 9L) respond "unable" although the controller cleared him for takeoff. The departure subsequently stopped the takeoff roll.

- *Go-around initiated by the LAHSO aircraft due to conflict with preceding arrival.* In another example (Miami, 1998), a go around was initiated by the LAHSO aircraft due to a conflict with an airliner that was slow to exit the LAHSO runway. The pilot reported that he had to make an evasive maneuver to avoid a departing B737. In this case, the pilot of the LAHSO aircraft reported that: 1) he did not receive an advisory regarding traffic, and 2) TCAS "did not provide guidance."

- *Increased potential for dual go-arounds.* In another event at Miami, aircraft "1" was cleared to land on runway 12 and hold short 9R. Aircraft "2" landed on the full-length runway 9R and mistakenly began to turn off onto the hold short runway 12. Although Aircraft "2" realized his mistake and turned back unto 9R, air traffic issued a go-around to aircraft "1." At the same time, aircraft "3," approaching to land on the full-length runway 9R, initiated a go-around due to aircraft "2." Aircraft "3" had to make an evasive maneuver to avoid aircraft "1." (The reporter was working ground control.)

LAHSO procedures resulting in increased use of rejected landing. FAA-Flight Standards material contains criteria for when to execute a rejected landing. It is possible that, under certain circumstances, these criteria may increase the use of rejected landing procedures to avoid a perceive hold short overrun risk.

2. Responsibility for Separation During a Rejected Landing

There is also legitimate disagreement over how responsibility for safely conducting a rejected landing should be shared between the pilot and controller. From the pilot perspective, the angle of the flight deck and pilot workload during a rejected landing make "see-and-avoid" problematic at best. However, from the controller perspective, it is difficult to assess the performance capabilities of the aircraft during this operation.

B. Summary of Existing Controls

As part of the February 9 agreement, pilots and controllers are collaborating on a set of procedures that would apply to specific airports. There are two broad types of procedures being considered: 1) procedures for runways that do not require a rejected landing instruction, and 2) procedures for runways which require a rejected landing instruction. According to FAA Notice 7110.199:

1) The following assumptions are used to determine the need for a rejected landing instruction for an aircraft accepting a LAHSO clearance: a heading and/or altitude assignment for the LAHSO aircraft is required if, for the full-length landing aircraft, the distance from the arrival runway threshold to the intersection where the hold short clearance is effective is less than 3,000 feet; a heading and/or altitude assignment for the LAHSO aircraft is required if, for the full-length departing aircraft, the distance from the departure runway threshold to the intersection where the hold short clearance is effective is greater than 2,000 feet.

2) If a rejected landing becomes necessary, the pilot will promptly notify ATC. Heading and/or altitude assignments will be flown as published until directed otherwise by ATC.

3) The procedures are intended to provide protection against a conflict between aircraft where neither the pilot nor the controller is able to effectively do so.

The Notice further provides that: "a controller will be responsible for issuing safety alerts in accordance with FAA Order 7110.65. It is further understood that pilots are always responsible for the general flight rule that they see and avoid other aircraft."

C. Hazards That Could Degrade Existing Controls

Several participants expressed dissatisfaction with the 3,000/2,000 ft criteria for arrival and departure intersections. They noted that there is so much variation in aircraft performance (especially since new requirements restrict the types of LAHSO aircraft, but not the types of full-length "passive" LAHSO aircraft) that, in many instances, these criteria may be inadequate. One participant noted some rejected landing procedures may require a VFR aircraft, or an IFR aircraft that has accepted a visual approach, to fly into instrument meteorological conditions in the event of a rejected landing. "The visual approach has no missed approach segment," noted this participant, "and therefore the aircraft must remain in VMC in the event of a rejected landing, possibly in direct conflict with the published rejected landing procedure."

D. Suggested Risk Reduction Strategies

Although the team did rate risks associated with rejected landings, the specifications of current controls are still being developed and so these ratings have limited value. It is clear that the most appropriate solution to the rejected landing issue will entail collaboration between FAA-Air Traffic, Flight Standards, and representatives from pilots' groups and controllers union. Work between these groups to establish adequate procedures is continuing at the time of this writing.

One group has suggested using modeling to validate any rejected landing instruction—although they did not specify exactly which tools or processes would be employed. Information received from Flight Standards and a commercial vendor indicates that computer based modeling of rejected landing procedures is feasible. For example, computer modeling has been used to study the capacity and safety characteristics of simultaneous offset instrument approaches (SOIA) to parallel runways.

Suggested risk reduction strategy:

16. **The FAA and Industry should continue to develop collaboratively rejected landing procedures.** This collaborative approach should consider:

- The points from which the rejected landing is initiated.
- Potential conflict with terrain or obstacles along the rejected landing flight path.
- Potential conflicts with other procedural requirements. E.g., visibility requirements—does the procedure take a VFR flight into instrument meteorological conditions? Is there a possible conflict between a rejected landing procedure and a one-engine out procedure for the full-length aircraft?
- Performance of the LAHSO aircraft and the full-length aircraft.
- Consideration of different full-length traffic scenarios (e.g., arrival, departure, go-around).

While the Office of System Safety does not endorse the use of any particular software, it notes that a variety of tools—e.g., simulation, computer modeling, etc.—are available and could assist in validating rejected landing procedures. For example, computer modeling has been used to study the capacity and safety implications of various SOIA (simultaneous offset instrument approach) procedures.

VIII. Risks Associated with Wet and Contaminated Runways

A. Hold Short Overrun and Collision Due to Wet Runway

In Phase I of this risk assessment, the FAA team identified a hold short overrun and collision as a result of a wet or contaminated runway as a critical risk. This assessment was based primarily on the assumption of reduced braking capability on wet runways (see Table VIII.1 for ERC wet runway data). This conclusion is consistent with the event history. As noted above, over 70% of 14 CFR part 121 landing overrun accidents investigated by the NTSB during the period 1994-1998 occurred on wet runways. The rejected takeoff accident history provides additional evidence of the hazards associated with wet runways. Between 1965 and 1990, large certificated air carriers accumulated 135.2 million scheduled and non-scheduled domestic departures. A study by the FAA Office of Aviation Policy and Plans estimated that approximately 94% of these were dry runway takeoffs—therefore, during that period there were approximately 127.1 million dry and 8.1 million wet runway takeoffs.[38] In the same period, however, U.S. wet runway rejected takeoff overrun accidents (that resulted in substantial aircraft damage or hull loss) accounted for 31 percent of total U.S. accidents (36 percent of the cases where runway condition was reported).[39] These statistics imply that the wet runway rejected takeoff accident rate is seven times greater than the dry runway accident rate (0.493 accidents per million wet runway takeoffs versus 0.071 accidents per million dry runway takeoffs).

1. Description of Existing Controls

Existing policy regarding wet runways can be divided into near- and intermediate-term requirements. In the near-term, FAA Notice 7110.199 prohibits land and hold short operations unless the runway is dry (7110.199 9.a.2), where a "dry runway" is defined as having "no visible moisture" (7110.199 8.m). This prohibition is also included in Flight Standards Information Bulletins for general aviation and air transport operators. The February 9 agreement, however, leaves open the possibility of future LAHSO-wet procedures when "manufacturers have provided actual demonstrated landing distance figures on wet runways for the aircraft in question."

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[38] In a sample of 83 major U.S. cities, it was found that, on average, measurable precipitation fell on 114.5 days per year (31.3 percent). It is estimated that wet runway conditions exist, on average, 20 percent of the time on days having measurable precipitation. Thus, about 6 percent (20 percent of 31 percent) of all takeoffs actually occur on wet runways. Glasco, Donald, *Preliminary Regulatory Evaluation, Initial Regulatory Flexibility Determination and Trade Impact Assessment: Improved Standards for Determining Rejected Takeoff and Landing Performance*, FAA Office of Aviation Policy, Plans, and Management Analysis; October 1992.

[39] In a study of 95 rejected takeoff overrun accidents occurring between 1962 and 1990, FAA determined that accidents involving wet runways accounted for 40 percent of the total number of accidents (where the runway condition was reported). These statistics led to a revision in rejected takeoff and landing distance requirements to explicitly consider the hazards associated with wet runways.

Part 139 airports are required to "provide for the collection and dissemination of airport condition information to air carriers" (14 CFR §139.339). Inspection procedures, described in 150-series advisory circulars, call for: 1) regularly scheduled inspections of facilities (which must be conducted daily at part 139 airports), 2) continuous surveillance of certain airport activities such as fueling operations, 3) periodic condition evaluation of approach slopes and obstructions, and 4) special inspections during unusual conditions or situations such as changing weather.

Special inspections occur "after receipt of a complaint or as triggered by an unusual condition or event." Advisory Circular 150/5200-18B, Airport Safety Self-Inspection, identifies the following areas subject to special inspections:

- Pavement areas. After rain, check pavement areas for ponding and edge damming.
- Safety areas. Check storm sewer system, inspection before reopening a runway or taxiway following any construction/maintenance in or around that safety area, etc.
- Marking and signs. Determine if markings are visible at night, especially after rain.
- Snow and ice. Check to ensure that foreign objects have been picked up after snow/ice removal.
- Construction. Night inspections to ensure that warning lighting is adequate, and that equipment is parked in appropriate area.

Table VIII.1.—Selected FAA LAHSO Event Review Team Data Regarding Wet Runway Collision Risks

Primary Hazard	Contributors	Selected Events
LAHSO clearances during inappropriate weather conditions: thunderstorms, wet runways	Adverse weather conditions develop quickly.	*ASRS 419017*. Aircraft refused LAHSO, ATC issues go-around, wet runway and thunderstorms in area. *ASRS 399065*. Go-around issued after declining LAHSO Twice, Marginal VFR, rain and Wet Runway.

2. Hazards That May Degrade the LAHSO-Wet Controls

i. Hazards That May Degrade the LAHSO-Wet Ban

There are three general ways that the prohibition on wet runway LAHSO may fail: 1) failure to detect/identify the condition, 2) failure to report/communicate the condition, 3) the prohibition is circumvented. The team explored each of these possibilities. Figure VIII.1 shows a fault tree for the top event that LAHSO is performed on a wet runway when it is prohibited.

Failure to detect/identify. While pilots may obtain runway condition information from other pilots, company sources, and their own visual inspection of the runway, for the most part they rely on the air traffic system for this data. Air traffic, in turn, has three principle sources of information: 1) the airport, 2) visual identification of water/moisture from the tower cab, and 3) pilot reports.

Particularly in cases where precipitation or water on the runway is not obvious, the most important means of verifying the runway condition is by inspection. By letter of agreement, an airport will conduct runway checks if there is a possibility that the runway is wet. Also, although they are not required, some airports have pavement sensors. Team members identified several possible means whereby moisture on the runway may not be detected. For example:

- There may be a higher risk of detection failure during periods of transition between dry-to-wet or wet-to-dry conditions.

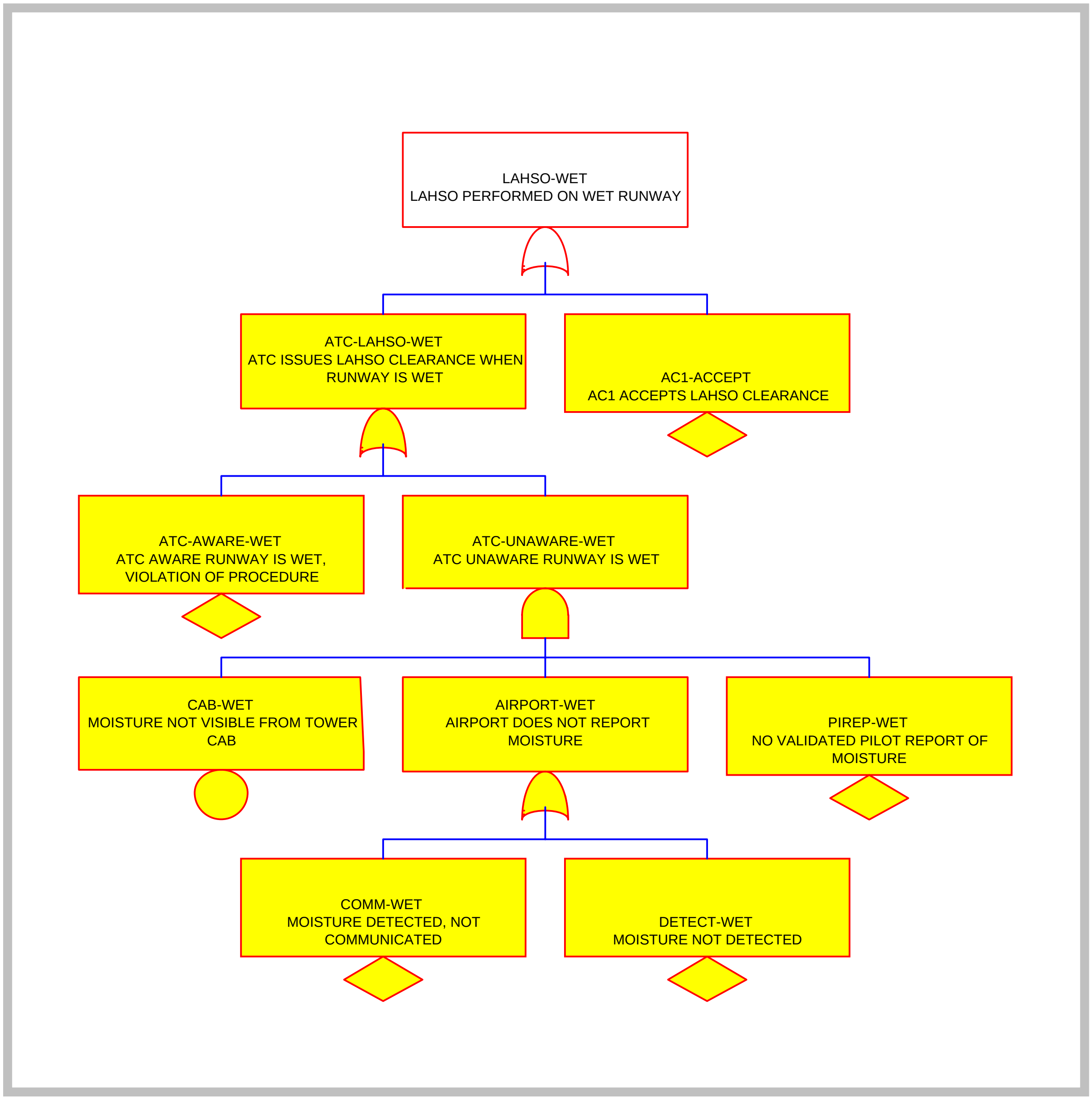
- The location of pavement sensors may also affect the probability of detecting moisture.

- It may be more difficult to detect moisture at night.

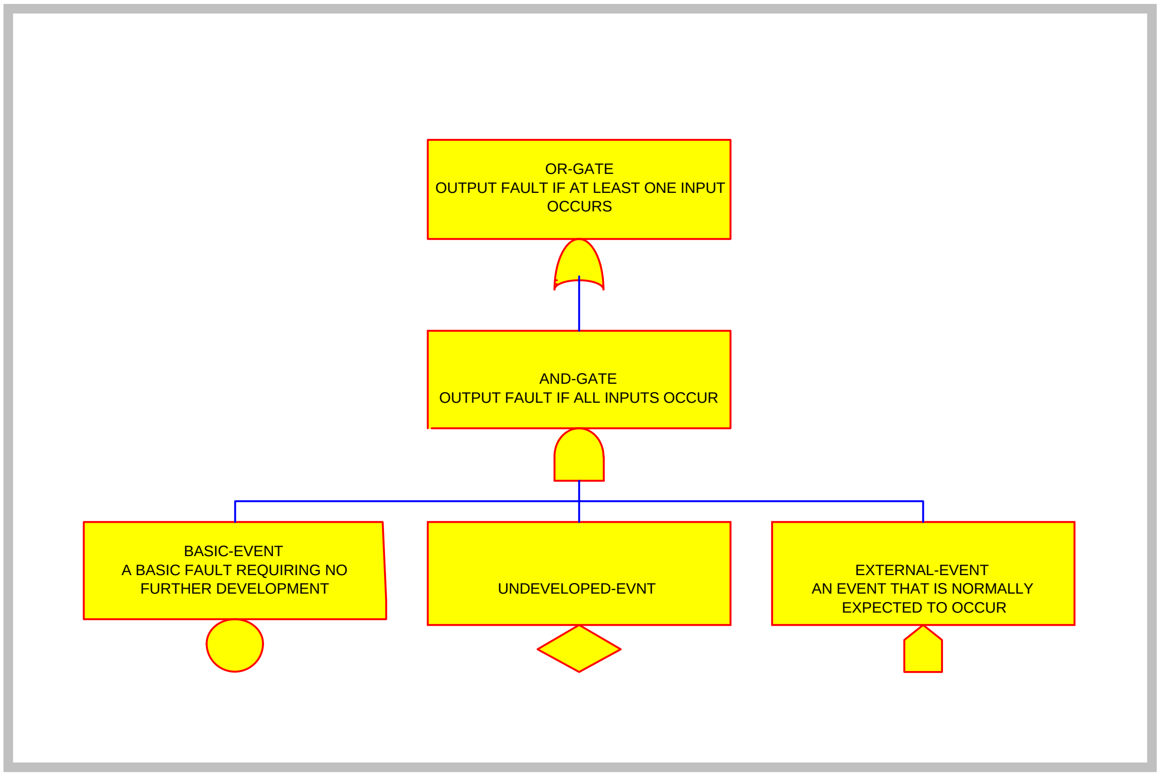
- Under some circumstances, asphalt runways can sweat and, therefore, be wet in the absence of precipitation.

One participant felt that 7110.199 did not adequately define the term “dry”, and that it was, in part, a subjective decision by the inspector.

Figure VIII.1—Wet Runway Fault Tree (Assuming LAHSO-Wet Prohibited)



Key to Figure VIII.1



Failure to communicate. Failure to communicate runway condition information in a timely manner could also lead to a failure of the LAHSO-wet prohibition. This is particularly true during a transitional period. Possible means whereby the runway condition may not be adequately communicated include:

- Some participants reported that there is often a reporting delay. The delay may be as long as 30 minutes between the time of an inspection and a runway condition change.

- Participants noted that air traffic may fail to ask for a runway condition report and that there is no requirement that the airport submit one in the absence of a request.

- An initial pilot report regarding less-than good braking may not be immediately conveyed by air traffic to subsequent pilots until there is verification of the initial report either by airport inspection or addition pilot reports.

Circumvention. Some participants noted that restrictions on LAHSO could be circumvented by issuing a hold short clearance on landing rollout. For example, if the runway is wet but the available landing distance is more than adequate (based on the observed performance of arriving aircraft), a controller could instruct a landing aircraft to hold short of an intersecting runway or turnoff before the intersection.

ii. Hazards That May Degrade the Intermediate-Term Control

As noted above, the February 9 agreement opens the possibility that LAHSO-wet may be permitted provided that manufactures provide "actual demonstrated landing distance figures on wet runways for the aircraft in question." While the FAA-industry team did not fully discuss this option, there are several concerns that this agreement raises.

- *Wet runway hazards are not limited to brake performance*. During the FAA team preliminary hazard identification exercise, several participants raised concerns regarding the conspicuity of markings and other aircraft in the presence of rain/water. Subsequent testing of LAHSO lighting configurations (see Section VI) also indicated problems with identifying the hold short point, even when lighted and at night, in rain.

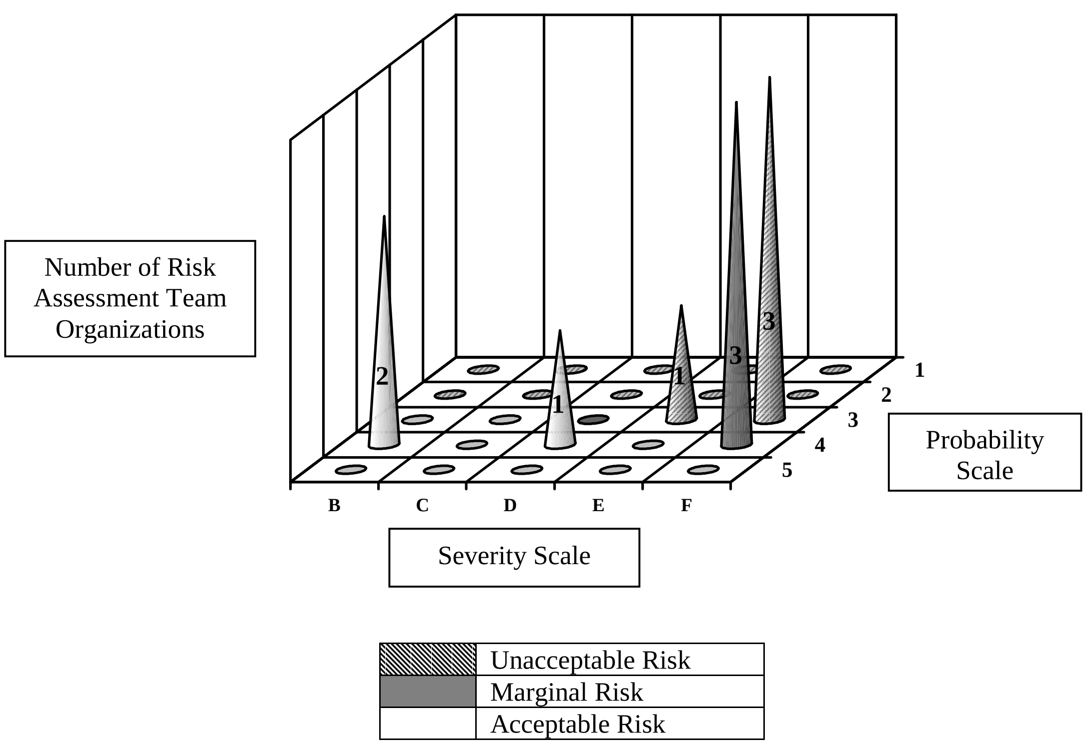
- *Manufacturers landing distance data may or may not provide adequate safety margins*. While manufacturers wet runway braking performance data is available, according to the FAA Aircraft Certification Service, only one transport category airplane model has developed flight test data of stopping performance on wet runways for the purposes of airplane certification. In addition, NASA and others have collected data on wet runway performance for research purposes.[40]

[40] See, for example: Engineering Sciences Data Unit (ESDU) 71026, Frictional and Retarding Forces on Aircraft Tyres, Part II: Estimation of Braking Force (Friction Data updated—1981).

Generally, these data show that wet grooved runway brake performance approaches that of dry performance. However, the actual friction capability of grooved and porous friction course runways varies depending on variables such as groove shape, depth, and spacing, method used to construct the grooves, type of pavement surface, volume and type of airplane traffic, frequency of pavement evaluations, and maintenance. Also, aircraft-specific factors (such as brake type, brake wear, tire wear, etc.) may also apply. These issues should be considered in the development of stopping distances for a LAHSO-wet standard.

3. Residual Risks

Figure VIII.2.—Subjective Assessment of Wet-Runway Collision Risk (Assuming LAHSO-Wet is Prohibited)[41]



i. FAA-Industry Team Assessment of Risks

Four organizations concluded that, although the likelihood of an accident is "low" (as defined in the risk rating matrix, see Section III), the risk of a collision as a result of a wet runway hold short point overrun, given the ban on LAHSO-wet, was unacceptable. All other organizations

[41] Voting organizations included: ATA, ALPA, SWA, RAA, AOPA, FAA-ASY, FAA-ATO, FAA-AAS, FAA-AFS, FAA-ASC.

rated the probability as "very unlikely." As noted above, however, the team did not fully consider the implications of LAHSO-wet procedures based on any manufacturer's wet runway performance data.

In the subsequent wrap-up meeting, team members expressed somewhat higher confidence in the LAHSO-wet prohibition. (The break between the working sessions and the wrap-up meeting, and the "homework" assignment afforded participants the opportunity to reconsider their original assessments.) Generally, the team agreed that the prohibition provided an acceptable level of risk—although there were still concerns regarding the actual implementation of this policy.

ii. Statistical Information

It is unlikely that wet runway operations constitute a significant fraction of LAHSO, and therefore there is little statistical data related to wet or contaminated runway events. Prior to FAA Order 7110.114, LAHSO-wet was permitted under waiver at only three airports (beginning in 1988).[42] The limited statistical data do raise concerns over the accuracy of runway condition information available to the air traffic controller and the flight crew. Two of the 120 ASRS/NAIMS reports cited wet runways. In one case, the reporter claimed that he was told the runway was dry only to discover upon landing that the runway was wet.

Some participants observed that the probability of LAHSO-wet is further constrained by Notice 7110.199 visibility requirements. An analysis of hourly weather observations from the National Climatic Data Center (NCDC) for the 6-year period 1990-1995, however, shows precipitation often occurs during visibility conditions that are permitted under 7110.199.[43]

4. Suggested Risk Reduction Strategies

i. Prohibition of LAHSO-wet

Although no industry member of the team offered a recommendation regarding wet runway hazard controls, the working session deliberations suggest some ways in which the controls can be improved (probably with little cost or impact on capacity). Team discussions indicated concern over the ability of air traffic to ensure that accurate runway moisture information will be available. This could have critical implications: LAHSO is assumed "on" by default, until a decision is made to terminate it. In this context, it means that LAHSO is "on," i.e., the runway is "dry," until it is determined to be "wet." On one hand, this seems to be an inconsequential point—the declaration of a "wet" runway may be obvious under most conditions. Nevertheless, participants expressed concerns over the procedures used to identify and communicate runway condition information to the air traffic controller and the flight crew, particularly during transitional periods. (It is interesting to note that in other contexts, decision-making is biased towards assuming a wet runway. For example, air carriers report that for dispatch purposes

[42] FAA, *Land and Hold Short Operations: Preliminary Risk Assessment, Op. cit.*, p 10.

[43] 1990-1995 NCDC hourly data for Reagan-National Airport (DCA) show that visibility was better than 1000 ft/3 miles in approximately three-quarters of the observations where measurable precipitation was recorded.

accelerate-stop distance calculations assume a wet runway if there is a possibility of rain, i.e., many takeoffs are made under stopping distance computations that assume the runway is wet, when the runway is in fact dry.)

Suggested Risk Reduction Strategies:

17. **Responsibilities.** At airports conducting land and hold short operations, the airport and air traffic control should establish explicit guidelines concerning responsibilities for determination of a wet runway. These guidelines could be part of a letter of agreement (LOA), and should include provisions to ensure that the airport takes responsibility to inspect and notify air traffic of hazardous runway conditions without requiring that air traffic request a runway condition report.

18. **Timely detection.** At airports conducting land and hold short operations, the airport and air traffic control should establish procedures to ensure timely detection of moisture on the runway. These procedures should consider conditions under which inspections are made (e.g., day/night), frequency of inspections (particularly during conditions of threatening precipitation or intermittent precipitation), and the use of procedures other than inspections to determine runway condition (e.g., runway sensors). Again, these procedures could be formalized as part of a LOA.

19. **Timely notification.** Changes in runway condition could be critical to the safe conduct of land and hold short operations. The airport and air traffic control should establish procedures to ensure timely communication of runway condition reports, particularly during transitional periods.

ii. Future LAHSO-Wet Standards

As noted above, the February 9 agreement opens the possibility of permitting LAHSO-wet. However, the agreement only speaks to brake performance under wet conditions. Other considerations include:

20. **All changes to existing LAHSO controls, including conditions for LAHSO-wet, should be evaluated in accordance with the requirements of FAA Order 8040.4, Safety Risk Management.** As noted above, wet/contaminated runways account for a disproportionate share of accidents where stopping performance is critical (see the landing overrun and rejected takeoff data). Before developing policies for and approving LAHSO-wet, the FAA should conduct a risk assessment of wet runway land and hold short operations to include a thorough identification of hazards, analysis of accident scenario likelihoods and severities, and an assessment of risks against acceptability criteria. (See Section V for a full discussion.) Hazards to be considered should include (but are not limited to):

    - Effects of water/precipitation on marking/signage conspicuity
    - Effects of water/precipitation on lighting conspicuity

- Effects of water/precipitation on conspicuity of intersecting traffic
- Possible synergistic effects of water/precipitation and night-time land and hold short operations
- Effects of runway type/condition (e.g., treatment type, groove shape, groove spacing, depth, method used to construct grooves, volume of airplane traffic, frequency of evaluations and maintenance, etc.) and adequacy of current runway inspection/maintenance Advisory Circulars for application to LAHSO.
- Aircraft systems (e.g., brake type, effects of wear on brake performance, anti-skid technology, etc.)

Further research into these issues could be conducted as part of the site-specific risk assessments (see Section X).

B. Hold Short Overrun and Collision Due to Contaminated Runway

The FAA team identified a hold short overrun and collision due to a contaminated runway as a critical risk that required further study by the government-industry team. Again, this preliminary assessment (which assumed “minimal controls”) was based on the known risks of runway contamination.

1. Description of Existing Controls

Other than in the definition section, there is no explicit reference to contaminated runways in FAA Notice 7110.199. The Notice, however, does instruct air traffic to terminate LAHSO if hazardous conditions exist—which would include runway contaminants. Air traffic’s primary source of information regarding runway condition, again, is the airport. Part 139 airports perform daily visual inspections of runways.[44] In addition, airports may conduct periodic inspections and maintenance for rubber contamination.

Advisory Circular AC 150/5320-12C (*Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces*) contains guidelines for runway inspection and maintenance. Requirements vary depending on runway usage both in terms of landing frequencies and airplane type. The minimum friction survey frequency recommended in AC 150/5320-12B ranges from once per year (if usage is less than 15 landings per day) to once per week (greater than 210 landings per day). Suggested rubber removal frequency ranges from once every two years (less than 15 landings per day) to once every two months (greater than 210 landings per day). Recommended inspection and rubber removal intervals are adjusted if widebody transports constitute more than 20 percent of landings.

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[44] 14 CFR part 139 prescribes rules governing the certification and operation of land airports which serve any scheduled or unscheduled passenger operation of an air carrier that is conducted with an aircraft having a seating capacity of more than 30 passengers. This part does not apply to airports at which air carrier passenger operations are conducted only by reason of the airport being designated as an alternate airport.

2. Hazards That Could Degrade Existing Controls

FAA-industry team participants enumerated possible sources of runway contamination that may be difficult to detect. These included: 1) liquid chemicals, fuels, or oils, possibly from an aircraft, 2) bird excretions, 3) possible seepage of chemicals from the runway surface, 4) a layer of ice on the runway surface. Some participants again expressed concern over whether the current system of controls could adequately predict, detect, and/or communicate the presence of contamination.

3. Residual Risks

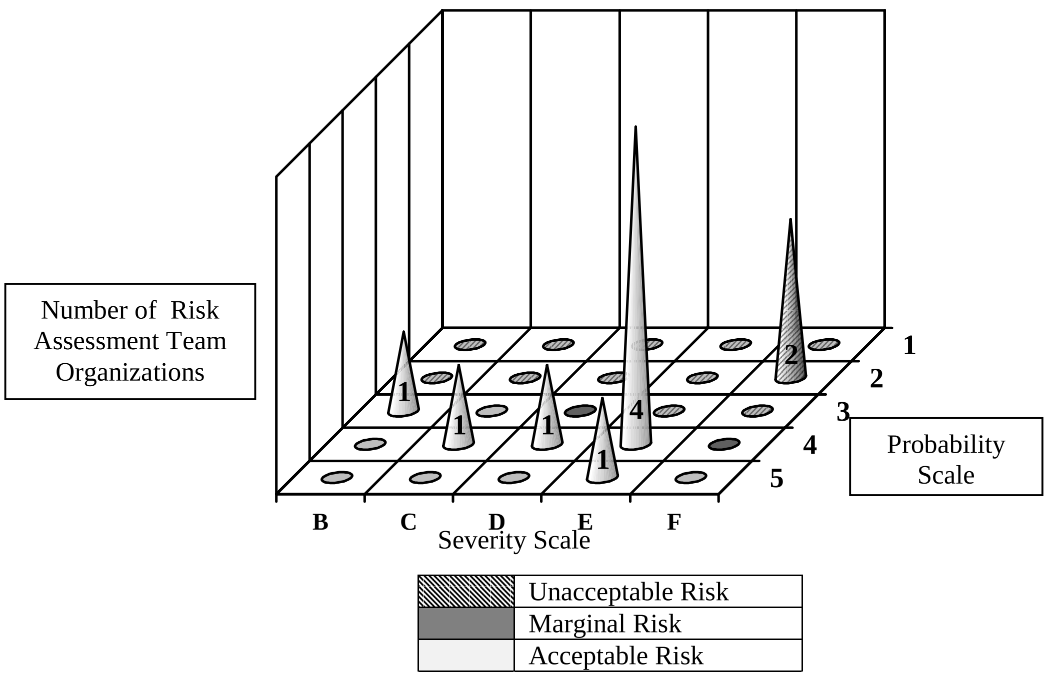
i. FAA-Industry Team Assessment of Risks

During the working sessions, two organizations assessed the risks of a hold short overrun and collision on a contaminated runway to be unacceptable risks. All other participants judged the existing controls to be acceptable. During the subsequent wrap-up session, the team generally agreed that existing controls provided an acceptable level of risk. Team ratings are illustrated in Figure VIII.3.

ii. Statistical Information

The Office of System Safety is unaware of any LAHSO events that involved a contaminated runway.

Figure VIII.3.—Subjective Assessment of Contaminated-Runway Collision Risk (Assuming LAHSO-Wet is Prohibited)[45]



4. Suggested Risk Reduction Strategies

The FAA-industry team did not recommend any additional controls regarding contaminated runways. However, this assessment was made in consideration of a ban on LAHSO-wet. (Rubber was recognized as a critical runway contaminant since, combined with moisture, it can significantly degrade braking. But, if LAHSO-wet is prohibited, existing controls relating to rubber contamination were considered acceptable.)

Suggested Risk Reduction Strategies:

See Risk Reduction Strategy 20.

[45] Voting organizations included: ATA, ALPA, SWA, RAA, AOPA, FAA-ASY, FAA-ATO, FAA-AAS, FAA-AFS, FAA-ASC.

IX. Other Issues

A. Night LAHSO

1. Summary of Findings

During the risk rating exercises, many scenarios were rated twice; once for "day" conditions and once for "night." Generally, the team concluded that night-LAHSO risks were acceptable provided that "appropriate controls" were in place. Some members of the team, however, expressed concerns over the relative risks of conducting LAHSO at night—even with lights at the hold short intersection.

As noted earlier, the probability of a LAHSO collision depends on:

- $P(x_1,\ldots,x_n)$ the probability of a specific combination of conditions.
- P_{HSO} the likelihood that a hold short overrun occurs if the hazardous conditions are present.
- P_{COL} the probability that two airplanes would be in the same place at the same time in the event of an overrun.

Night/darkness, then, affects the probability of a LAHSO collision in two ways. First, in the absence of controls (e.g., lights), it is more difficult to see the hold short point, and hence more likely that a hold short overrun occurs. Second, it also may make a collision more likely given a hold short overrun (recall that about one-third of ASRS/NAIMS events involve some type of evasive maneuvering).

Existing controls emphasize $\mathrm{P_{HSO}}$: Non-automatic LAHSO lights (i.e., lights that are on whenever the runway is LAHSO-eligible regardless of whether a given arrival is instructed to hold short) make the hold short point more visible. However, they do not address the second conditional probability, $\mathrm{P_{COL}}$: What happens if there is a hold short overrun? The event data shows that many overrun and go-around events involve errors not related to the conspicuity of the hold short point. Can night (or a background of city lights) affect the ability of controllers and flight crews to detect a potential conflict?

There is very little historical data relating to night LAHSO operations. There is, however, accident data which relates to the issue of night landing risks.

Atlanta, Georgia, January 18, 1990. A B727 collided with a Beech A100 after landing at night. With respect the the conspicuity of the Beech, the NTSB concluded:

> The Safety Board's examination of available light bulbs from N44UE confirms that some [aircraft anticollision] lights were not illuminated at impact…In the lighting configuration

> "NAV" lights only, the aft portion of the King Air aircraft would present only a single rear white position light, with an intensity of 20 candle power, to be acquired by the following airplane. Thus, only limited conspicuity would be afforded in a field of view that included a variety of runway, taxiway, and other lights.

The NTSB also noted that it is the prerogative of all pilots under 14 CFR 91.73(d) to "turn off the anticollision light system in the interest of safety if it proves distracting."

> In the case of the King Air airplane, the wing tip strobe lights, engine nacelles and propellers are close to the pilot's position….the Safety Board concludes that under the conditions that existed at the time of the accident, the pilot would most likely have turned off these lights.

Los Angeles, California, February 1, 1991. A landing B737 collided with a Fairchild Metroliner. With respect to the conspicuity of the Metroliner, the NTSB concluded:

> …investigation disclosed that the Metroliner's navigation/position lights and red anticollision beacon…were the only lights illuminated on the airplane at the time of the collision. However, during an additional conspicuity exercise, it was visually evident from both the tower and the final approach that aircraft and runway lights tend to blend together, perceptually.

The analysis of overrun and rejected landing/go-around events in the ASRS/NAIMS data raises some concerns over the adequacy of the LAHSO lights as a control for night LAHSO operations. As noted earlier, many (if not most) overrun and go-around events do not involve a failure of the LAHSO aircraft crew to recognize the hold short point. At the same time, the data show that many events involve evasive maneuvering. "See-and-avoid," then, appear to be a critical element of the LAHSO control set

It should be noted that, while the team ratings indicate some concerns over night LAHSO, no participant made any recommendations to alter or prohibit this practice.

2. Suggested Risk Reduction Strategies

21. Study night LAHSO risks as part of site-specific risk assessments. The discussion above and the team's subjective rating of "day" versus "night" risks suggests that the issue of night LAHSO should be investigated during the site-specific risk assessment (see Section X). Based on the results of this risk assessment, consideration could be given to limiting or prohibiting LAHSO-night procedures at certain airports or by certain operators.

B. Aircraft Systems

A LAHSO hold short overrun could result from two types of aircraft system issues: 1) failure or malfunction of an aircraft system, and 2) aircraft system design that does not permit the aircraft to stop within its expected required landing distance.

1. Failure or malfunction of an aircraft system

The FAA team considered three generic types of system failures during Phase I of the risk assessment: 1) those relating directly to the hydraulic/brake system, 2) those relating to ancillary systems which are related to aircraft braking (spoilers, anti-skid, etc.) and 3) other aircraft systems. Again, the hazardous scenarios were rated according to the likelihood of an accident conditional on the aircraft system failure.

Failure of the hydraulic/brake system in the context of LAHSO refers to those accidents in which there was a complete failure of the brake system *that was unknown to the pilot before she/he landed*. A search of part 121 landing overrun accident/incident histories for the period 1994-1998 did not find an event which met this criterion. For example, in November 1998 a B737 experienced a loss of the hydraulic system and veered off the runway during the landing rollout. However, this failure occurred during climb-out, the crew subsequently returned to Hartsfield Atlanta International to make an emergency landing. Clearly, in this scenario, it is extremely unlikely that the crew would have received or accepted a land and hold short clearance.

A search of part 91 landing overrun accident/incident histories for the period 1994-1998 discovered seven incidents where brake failure led to an accident. These data reflect, in part, the greater redundancies in 14 CFR part 25 (transport category) aircraft relative to part 23 aircraft with respect to hydraulic/braking systems.

There are seven LAHSO reports that involved a mechanical problem in the ASRS/NAIMS data for 1994-1998—none related to a complete failure of the hydraulic/brake system. The equipment problems included: 1) struck by lightning on 8 mile final, 2) anti-skid cycling, 3) unspecified equipment problem, 4) no gear lights, 5) dim gear light, 6) smoke in cabin, 7) suspected reverse thrust problem. Two of these involved a hold short overrun; numbers "2" and "3."

2. Aircraft System Design

A hold short overrun could also result if the pilot's expectation of aircraft performance is different from its actual capability. One possible scenario involves a design change to the aircraft that is not accounted for by the pilot in computing her/his required LAHSO landing distance. For example, it is possible that a supplemental type certificate (STC) for a different brake may result in an increase in stopping distance. Discussions with an FAA Aircraft Certification Service engineer suggest that, while it is very unlikely that such a STC would be sought for a transport category airplane, it is possible that it might be sought for a part 23 airplane (for example, if the STC brake had longer wear). It should be noted, however, that a change in landing distance would have to be reflected in the Aircraft Flight Manual.

3. Suggested Risk Reduction Strategies

Current LAHSO controls include restrictions on general aviation-to-air carrier LAHSO, and MEL restrictions governing systems that can affect the ability of the aircraft to stop (see Section VII). The FAA internal process placed this hazard at a lower level of priority; as a result it was not fully analyzed by the FAA-industry team. However, the team did not make any additional recommendations regarding aircraft systems in the "homework" exercise.

C. General Aviation

Table IX.1.—Selected ERC ASRS/NAIMS Data Regarding General Aviation LAHSO Risks

Hazard	**Historical Events**
Inadvertent overshoot of hold short point due to GA pilot lack of knowledge/skill.	*HOU Pilot Deviation*. Landing Grumman AA-5 fails to hold short and departing B-737 aborts takeoff. *SBA ASRS 361150*. IFR training flight with instructor and pilot under hood on ILS with LAHSO clearance. Student's hood removed at 100' AGL, too far down the runway to stop. *BUR ASRS 405615*. General Aviation aircraft unable to hold short. May not have acknowledged LAHSO. Air Carrier at taxi speed at intersection. *PWM ASRS 383107*. General aviation aircraft failed to stop prior to hold short point, but not runway. B-737 on full-length runway had already turned off. *PNE ASRS 376959*. Aircraft porpoises on landing and goes-around with departing traffic. Must bank to miss traffic (NMAC). PNE ASRS 376770. PA-28 goes-around and must bank steeply to miss departing PA-31. (NMAC). BUR ASRS 370383. PA-32 is high and fast on landing goes past hold short point but not runway. Tie at intersecting runway as both aircraft stop. BUR ASRS 375210. Single engine aircraft goes-around and misses commuter on departure. (NMAC).

Selected ERC data regarding general aviation LAHSO are shown in Table IX.1. Participants shared several concerns, especially with respect to general aviation-to-air carrier LAHSO (i.e., where the general aviation aircraft is the LAHSO aircraft and the air carrier aircraft is a "passive" full-length participant): 1) the different levels of LAHSO training and procedures required for air carriers and air carrier pilots versus general aviation operators, 2) the possible differences in pilot skill levels, and 3) possible differences in aircraft systems (e.g., braking system redundancy).

The ASRS/NAIMS data do indicate, for example, that skill level is a risk factor. This conclusion most likely follows from the fact that the skill levels of commercial pilots are homogeneous relative to their non-commercial counterparts. While many general aviation pilots are highly experienced, there is probably greater variability in skill levels in this population. The accident/incident data also suggest greater skill variability in the part 135 pilot community.

The current policy prohibiting a non-air carrier aircraft (defined as any operator other than 14 CFR part 121) LAHSO to an air carrier was seen as an acceptable control. The FAA-industry team did not recommend any additional restrictions to non-commercial aircraft land and hold short operations.

X. Next Steps

A. Hazard tracking and monitoring

Properly implemented, LAHSO is a critical capacity enhancing procedure. In order to ensure that its evolution continues to enhance safety, the Office of System Safety believes that the FAA needs to establish a hazard tracking and monitoring process to assess the effectiveness of current and future controls. For example, this function could simply be an extension of the current Event Review Committee. This process should include:

22. **Site-specific risk assessments.** Risk assessments to be performed at specific sites (e.g., based on frequency of LAHSO operations, accident/incident or event reports, etc.). The Office of System Safety could assist in coordinating this effort.

23. **Hazard tracking and monitoring.** Tracking and monitoring of event reports.

24. **Periodic system-wide collection of LAHSO activity data.** Surveys would be done periodically (with the timing of the survey's "seasonally adjusted" to enable year-to-year comparisons), to record:

- The number of LAHSO clearances
- Types of operations involved (both "active" and "passive")
- Controller and pilot concerns regarding the procedure.

B. Application of Safety Risk Management Principles

25. **Application of Safety Risk Management principles.** All revisions to the existing system of LAHSO controls and all waivers to existing regulations should be subjected to a safety risk management (SRM) process (e.g., as defined in FAA Order 8040.4). For example, in the case of waivers to specific regulations, SRM could be used to develop a process and criteria by which applications for waivers would be evaluated. This would maximize the likelihood that a consistent safety policy was applied to all waiver petitions.

C. Joint government/industry education program for general aviation

26. **General education and training programs.** FAA and industry should launch an education and awareness program. This program would also develop and distribute accurate, non-technical and readable materials related to LAHSO safety.

D. Issuing Hold Short or Turn-Off Instructions After Landing

Several participants raised a concern that LAHSO restrictions may be circumvented by issuing hold short instructions after landing. In many cases, these instructions may pose no safety issue.

However, in some cases such instructions may increase risks since many LAHSO controls would no longer apply even though LAHSO-like risks may apply. Additional controls would include:

27. **Hold short/turn-off instructions after landing: controller education.** Education/training and policy guidance material for air traffic controllers and pilots to remind them that hold short instructions after landing should not be used as a way to circumvent LAHSO controls.

28. **Hold short/turn-off instructions after landing: pilot education.** Education/training and policy guidance to pilots to remind them that hold short/turn-off instructions should not be accepted (i.e., the default is "unable") unless the pilot can see the hold short point or taxiway, and is capable of stopping and/or exiting at that point. This decision should take into consideration runway conditions.

29. **Intersecting traffic should be notified of traffic holding short.**

Appendix I: Preliminary Hazard List

I. Aircraft
- A. Brake/hydraulic system failure/malfunction
- B. Anti-skid inoperative
- C. Landing gear failure
- D. Tire failure
- E. Thrust reverse inoperative
- F. Other System failure/malfunction

II. Flight crew
- A. Crew coordination/procedures
  - 1. Lack of pre-flight preparation on possible LAHSO
  - 2.. Inexperience crew
  - 3. Poor use of ACARS/ATIS information to prepare for possible LAHSO
  - 4. LAHSO after instrument approach
  - 5. Lack of familiarity with airport
  - 6. Misinformation on ALD required for aircraft/conditions
  - 7. Poor crew communication/coordination
    One crewmember accepts LAHSO, does not tell the other
  - 8. Poor crew/ATC communication
  - 9. Pilot acceptance and subsequent rescission
  - 10. Pilot fails to give correct LAHSO read-back
  - 11. “One-way” communication
  - 12. Pilot report of poor braking passed on to ATC
  - 13. Crew does not (cannot) see other traffic on the ground
  - 14. Missed approach, go-around, balked landing
  - 15. Procedures (or lack of procedures)
  - 16. Poor communication during missed approach
  - 17. Deck angle on go-around inhibits visual separation
  - 18. Pilot busy/distracted
  - 19 Pilot does not see hold short point (see III. Airport/Runway Hazards)
- B. Landing technique
  - 1. Landing long
  - 2. Landing fast
  - 3. Delayed application of braking measures
  - 4. Pilot loss of perception

Appendix I: Preliminary Hazard List

III. Airport/Runway
- A. Design
  1. Runway/taxiway intersection points (impact forces)
  2. Angle of intersection (ability to see intersecting aircraft)
  3. Presence of negative runway gradient
  4. Runway bearing in relation to wind direction (see II.B.)
  5. Insufficient safety area, stopways, overrun area
  6. Presence of ground hazards near runway intersection
  7. Wildlife/people
  8. Vehicles
  9. Structures
  10. Multiple hold-short points per runway
  11. Inability to see parts of runway from tower
- B. Operation
  1. Changes in terminology
  2. Obstacles
  3. Poor/inadequate signage
  4. Fading markings on pavement
  5. Glare/water inhibiting conspicuity
  6. Damage to signs
  7. Changes in markings
  8. Lighting (inoperative?)
  9. Misinformation on ALD
  10. Runway bearing in relation to wind direction
      - a. Crosswind
      - b. Tailwind
      - c. Gusts
  11. Misinformation on runway condition (friction measurement)
      - a. Variability in friction along the runway length
      - b. Variability in friction during the day
      - c. Poor calibration of friction measuring equipment
  12. Lack of communication to ATC regarding runway condition
  13. Pilot reports of poor braking not passed on to airport (for friction test)
  14. Wet/contaminated runway
      - a. Maintenance
      - b. Wet (visible moisture)
      - c. Fuels
      - d. Rubber
      - e. Other debris

Appendix I: Preliminary Hazard List

IV. Air Traffic System
- Missed approach procedures
- Balked landing procedures (or lack of)
- ATIS does not advise of possible LAHSO
- Approach does not advise of possible LAHSO
- Tower issues LAHSO "late"
- Crew lack of time to plan LAHSO
- Lack of coordination between approach and tower
  - a. E.g., "Keep speed up"
- Lack of controller experience
- LAHSO not given, but controller asks aircraft to turnoff at taxiway
- Pilot report of poor braking not heard or ignored
- Pilot report of poor braking not reported to other pilots
- Controller gives inaccurate information on runway ALD
- Communication with airport regarding runway condition
- ATC issues "punitive" go-arounds for aircraft declining LAHSO
- Distraction caused by having to look up LAHSO data
- Controller distracted from monitoring LAHSO aircraft near intersection
- Lack of controller consideration of possible go-around

VI. Man-made
- Wake turbulence
- Vehicles on runway
- Noise abatement requirements

Appendix II: Listing of Suggested Risk Reduction Strategies

1. **Approval of LAHSO at specific airports**. The FAA should consider applying more rigorous approval criteria that would restrict LAHSO only to those airports where there is a significant, demonstrated economic/capacity need.

2. **Controls to minimize P_{COL}.** The FAA should consider developing procedures whereby LAHSO and full-length aircraft are sequenced to minimize the likelihood of a collision even if the LAHSO aircraft cannot stop before the hold short point (e.g., using tables or computer algorithm/display tools).

3. **Improved cooordination between approach and tower**. FAA-Flight Standards material requires that the pilot in command advise, upon initial contact, if a LAHSO clearance cannot be accepted. ASRS data, however, indicate that this information is not always coordinated between approach and tower. A possible improvement is to establish, where practicable, procedures whereby this information is coordinated between approach and local controllers.

4. **Foreign air carrier participation in land and hold short operations**. While, the risk assessment team did not have the opportunity to fully analyze the possible safety implications of foreign air carrier participation in LAHSO (since, at the time of the risk assessment working sessions, its understanding was that such operations were prohibited), it did identify foreign carrier operations as a potential hazard with respect to communications. Recently issued Flight Standards guidance material, however, lays out criteria for such operations.

   The FAA should develop risk-based standards for evaluating and approving foreign air carriers for participation in LAHSO before permitting such operations as a National Policy. Issues that should be considered include (also see Section IX):

   - Possible miscommunication (using emergency or non-standard phraseology) between foreign pilots and ATC during a rejected landing.
   - Possible effects of lack of airport familiarity on accident/incident likelihoods.
   - Possible effects of LAHSO lighting configuration on foreign crew not familiar with the U.S. configuration. Also, possible safety issues concerning differing LAHSO lighting standards between countries.
   - Possible effects of lack of LAHSO procedure familiarity on hold short overrun or rejected landing likelihoods.
   - Variability of English skills within a given foreign carrier.

Appendix II: Listing of Suggested Risk Reduction Strategies

5. **Anti-stuck microphone and anti-block radio technology.** Require the use of anti-stuck microphone and anti-blocking radio technology for air traffic equipment and radio equipment in aircraft operating at ATCT where LAHSO are permitted.

6. **Site-specific studies of radio interference.** As part of the site-specific risk assessments and on-going hazard tracking programs (see Section X) airports and air traffic should establish programs to ensure the quality and integrity of voice communications.

7. **Pilot training: "passive" LAHSO.** LAHSO training should not be limited to operators conducting LAHSO. Pilot training material should include information on the criticality of communications errors during LAHSO. This material should address hazards associated with communications errors involving the full-length (i.e., non-LAHSO) aircraft, and emphasize the need for the intersecting aircraft to acknowledge the LAHSO advisory.

8. **Non-voice communications.** The FAA should investigate the application of non-voice technologies for exchanging information between controllers and flight crews (e.g., datalink) during a land and hold short operation.

9. **Automated LAHSO light system.** As noted above, industry and the FAA are already investigating the use of an automated system of LAHSO lights. Such a system would give positive visual confirmation of voice (or datalink-type) LAHSO clearances. *However, the FAA should not commit to the implementation of an automated LAHSO light system until a Preliminary Hazard Assessment (PHA) of the system concept is completed (see Section VI).*

10. **Do not implement the interim two-bar configuration without evaluation and testing.** Implementation of the two bar system should commence only after thorough testing and evaluation to determine its effects on: 1) the likelihood of exiting delays, 2) delays for subsequent traffic and collision/conflict likelihoods, 3) intersecting traffic, and 4) the net benefits of a two-bar system over the single-bar system.

Appendix II: Listing of Suggested Risk Reduction Strategies

11. **Do not commit to an automated two-bar system until a thorough Preliminary Hazard Assessment (PHA), that includes simulation testing, is completed**. In principle, an automatically controlled system of LAHSO lights may mitigate many hazards including the those associated with communications errors and conditioning pilots to pass through pulsing lights. However, many detailed questions must be answered before making a final commitment to automated lights. These issues include:

    - Are there potential hazards associated with lights that come on or off for an operation on an intersecting runway?
    - For a condition where the LAHSO aircraft is followed by a full-length arrival, when are the lights turned off? Before the LAHSO aircraft is cleared to cross a hold short runway. After?
    - For a condition where a full-length arrival is followed by a LAHSO arrival, when are the lights turned on? While the first aircraft is still on the runway? After it has cleared?
    - Will the lights be automatically turned on and off, or on only?
    - Will the algorithm that governs on/off states be the same for all airports? Are there airport or runway configuration specific issues that will require different algorithms for different sites?
    - Will the on/off algorithm require that the system know the position of all aircraft?
    - If algorithms are different for different airports. Could the conditions under which the lights are turned on or off be different for different airports? Is this a hazard?

12. **Minimize the likelihood of go-arounds as a result of declined LAHSO clearances.** It is clear that a critical hazard control in the LAHSO procedure is the pilot's knowledge of her/his aircraft state, personal condition, and comfort with a hold short operation. Team discussions and ASRS data, however, indicate that under some conditions pilots perceive that an "unable" response to a LAHSO clearance will result in a "punitive" go-around. It is not clear whether these cases are in fact punitive or simply the result of aircraft separation requirements that would not have permitted a full-length clearance. Whether or not they are intentional or punitive, go-arounds reduce the effectiveness of existing controls in that they may induce some pilots to accept landing risks that they would not otherwise take. Two measures to reduce the likelihood of go-arounds are:

    - Issue system-wide clarification of LAHSO policy regarding go-arounds issued after a rejected LAHSO clearance.
    - Improve coordination between approach and local controllers to minimize the likelihood of go-arounds—particularly after approach has been notified that an arrival is unable to hold short.

Appendix II: Listing of Suggested Risk Reduction Strategies

13. **Foreign air carrier participation in land and hold short operations**. The FAA should develop risk-based standards for evaluating and approving foreign air carriers for participation in land and hold short operations. (See Section VI.)

14. **Establish rejected landing procedures**. Guidance material from Flight Standards places emphasis on the importance of attaining an appropriate touchdown point. If this is not accomplished, the guidelines require a rejected landing. Thus, a "control" for the hold short overrun collision risk, is to transfer part of this risk to rejected landings. The effectiveness of this requirement to reduce the risks of a hold short overrun, then, depends on the degree to which safeguards are established for rejected landing procedures. In other words, the effectiveness of a requirement to execute a rejected landing is lessened if pilots perceive the subjective risks associated with a rejected landing to be greater than the risks associated with a hold short overrun. (See next Section).

15. **Experience.** Accident and incident data suggest a link between pilot experience and the likelihood that the hold short point will be overrun. The FAA should evaluate the need for establishing LAHSO experience requirements, including: 1) flight hours, 2) flight hours in type, 3) familiarity with airport/runway.

16. **The FAA and Industry should continue to develop collaboratively rejected landing procedures.** This collaborative approach should consider:

    - The points from which the rejected landing is initiated.
    - Potential conflict with terrain or obstacles along the rejected landing flight path.
    - Potential conflicts with other procedural requirements. E.g., visibility requirements—does the procedure take a VFR flight into instrument meteorological conditions? Is there a possible conflict between a rejected landing procedure and a one-engine out procedure for the full-length aircraft?
    - Performance of the LAHSO aircraft and the full-length aircraft.
    - Consideration of different full-length traffic scenarios (e.g., arrival, departure, go-around).

    While the Office of System Safety does not endorse the use of any particular software package, it notes that a variety of tools—e.g., simulation, computer modeling, etc.—are available and could assist in validating rejected landing procedures. For example, computer modeling has been used to study the capacity and safety implications of various SOIA (simultaneous offset instrument approach) procedures.

Appendix II: Listing of Suggested Risk Reduction Strategies

17. **Responsibilities.** At airports conducting land and hold short operations, the airport and air traffic control should establish explicit guidelines concerning responsibilities for determination of a wet runway. These guidelines could be part of a letter of agreement (LOA), and should include provisions to ensure that the airport takes responsibility to inspect and notify air traffic of hazardous runway conditions without requiring that air traffic request a runway condition report.

18. **Timely detection.** At airports conducting land and hold short operations, the airport and air traffic control should establish procedures to ensure timely detection of moisture on the runway. These procedures should consider conditions under which inspections are made (e.g., day/night), frequency of inspections (particularly during conditions of threatening precipitation or intermittent precipitation), and the use of procedures other than inspections to determine runway condition (e.g., runway sensors). Again, these procedures could be formalized as part of a LOA.

19. **Timely notification.** Changes in runway condition could be critical to the safe conduct of land and hold short operations. The airport and air traffic control should establish procedures to ensure timely communication of runway condition reports, particularly during transitional periods.

Appendix II: Listing of Suggested Risk Reduction Strategies

20. All changes to existing LAHSO controls, including conditions for LAHSO-wet, should be evaluated in accordance with the requirements of FAA Order 8040.4, Safety Risk Management. As noted above, wet/contaminated runways account for a disproportionate share of accidents where stopping performance is critical (see the landing overrun and rejected takeoff data). Before developing policies for and approving LAHSO-wet, the FAA should conduct a risk assessment of wet runway land and hold short operations to include a thorough identification of hazards, analysis of accident scenario likelihoods and severities, and an assessment of risks against acceptability criteria. (See Section V for a full discussion.) Hazards to be considered should include (but are not limited to):

- Effects of water/precipitation on marking/signage conspicuity
- Effects of water/precipitation on lighting conspicuity
- Effects of water/precipitation on conspicuity of intersecting traffic
- Possible synergistic effects of water/precipitation and night-time land and hold short operations
- Effects of runway type/condition (e.g., treatment type, groove shape, groove spacing, depth, method used to construct grooves, volume of airplane traffic, frequency of evaluations and maintenance, etc.) and adequacy of current runway inspection/maintenance Advisory Circulars for application to LAHSO.

- Aircraft systems (e.g., brake type, effects of wear on brake performance, anti-skid technology, etc.)
- Ability to detect and communicate in a timely way, changes in runway condition from "wet" to "contaminated."

Further research into these issues could be conducted as part of the site-specific risk assessments (see Section X).

21. Study night LAHSO risks as part of site-specific risk assessments. The discussion above and the team's subjective rating of "day" versus "night" risks suggests that the issue of night LAHSO should be investigated during the site-specific risk assessment (see Section X). Based on the results of this risk assessment, consideration could be given to limiting or prohibiting LAHSO-night procedures at certain airports or by certain operators.

22. Site-specific risk assessments. Risk assessments to be performed at specific sites (e.g., based on frequency of LAHSO operations, accident/incident or event reports, etc.). The Office of System Safety could assist in coordinating this effort.

Appendix II: Listing of Suggested Risk Reduction Strategies

23. **Hazard tracking and monitoring.** Tracking and monitoring of event reports.

24. **Periodic system-wide collection of LAHSO activity data.** Surveys would be done periodically (with the timing of the survey's "seasonally adjusted" to enable year-to-year comparisons), to record:
    - The number of LAHSO clearances
    - Types of operations involved (both "active" and "passive")
    - Controller and pilot concerns regarding the procedure.

25. **Application of Safety Risk Management principles.** All revisions to the existing system of LAHSO controls and all waivers to existing regulations should be subjected to a safety risk management (SRM) process (e.g., as defined in FAA Order 8040.4). For example, in the case of waivers to specific regulations, SRM could be used to develop a process and criteria by which applications for waivers would be evaluated. This would maximize the likelihood that a consistent safety policy was applied to all waiver petitions.

26. **General education and training programs.** FAA and industry should launch an education and awareness program. This program would also develop and distribute accurate, non-technical and readable materials related to LAHSO safety.

27. **Hold short/turn-off instructions after landing: controller education.** Education/training and policy guidance material for air traffic controllers and pilots to remind them that hold short instructions after landing should not be used as a way to circumvent LAHSO controls.

28. **Hold short/turn-off instructions after landing: pilot education.** Education/training and policy guidance to pilots to remind them that hold short/turn-off instructions should not be accepted (i.e., the default is "unable") unless the pilot can see the hold short point or taxiway, and is capable of stopping and/or exiting at that point. This decision should take into consideration runway conditions.

29. **Intersecting traffic should be notified of traffic holding short.**

Appendix III.—ASRS/NAIMS LAHSO Events, 1994-1998

Report Number	Mon/Yr	Time	Airport Id	Hold short Overrun? GAR? (Initiated by)	AC1 CFR	AC1 Type	Landing Distances 7110.196	AC2 CFR	AC2 Type	Basic Weather Conditions	Rnwy
427308	Jan-99	Day	GSO	Yes	91	?	na	?	?	VMC	14 hs 23
425528	Jan-99	Day	BOS	No	121	?	na	121	?	VMC	22L hs 27
423677	Dec-98	Day	YYC	No	121	?	na	121	?	VMC-Blowing snow	
422206	Dec-98	Day	YYC	No	121	MC-80	na	121	?	VMC	34 hs 10-28
423100	Dec-98	Day	FRG	AC1 GAR (AC1)	91	?	na	91	?	VMC	32 hs 1
420817	Nov-98	Day	DTW	AC3 GAR (ATC)	121	DC-9	na	121	B727	VMC	27L hs 21R
Prelim. OP Error IAD-T-98-E-012	Nov-98	Day	IAD	AC3 GAR (ATC)	121	?	na	91	?	?	?
OpError BWI-T-98-E-004	Aug-98	Day	BWI	No	121	?	na	121	?	VMC	28 hs 33L
419495	Oct-98	Day	CVG	No	121	?	na	121	?	VMC	18R hs 27
417092	Oct-98	Day	BDR	AC1 GAR (AC1)	91	?	na	91	?	VMC	Unk
414208	Sep-98	Day	ORD	No	121	?	na	121	?	VMC	Unk.
414200	Sep-98	Day	ORD	No	121	?	na	121	?	VMC	14R hs 27L
414192	Sep-98	Day	ORD	No	121	?	na	121	?	VMC	9R hs TWYS
414156	Aug-98	Day	ORD	No	121	?	na	121	?	VMC	9R hs TWY S
414168	Sep-98	Day	ORD	AC2 RI	121	?	na	121	?	VMC	9R hs TWY S
NMAC NSOT CLT98001&002 ASRS	Nov-98	Day	CLT	Yes	121	MD-80	6680	121	F-100	VMC	36R hs 5
417195	Oct-98	Day	MIA	No	91	GA-LTT/AC	na	121	?	Mixed	9R hs 12
419017	Oct-98	Day	ORD	AC1 GAR (ATC)	121	?	na	121	?	Mixed	14R hs 9R
416977 (See PD PGL-T-PWK-98-004)	Oct-98	Day	PWK	Yes	91	CE-310	4000	91	CE-172	VFR	16 hs 30
414424	Aug-98	Day	MIA	AC1 GAR (ATC)	121	2-eng Turbojet	na	121	?	VFR	9R hs 12
411438	Aug-98	Day	DFW	No	121	MD-80	6680	121	?	VFR	18R hs Twy B
411991	Aug-98	Day	ORD	AC1 GAR (ATC)	121	B727	5680	121	?	VFR	14R hs 9R
415997	Oct-98	Day	ORD	No	na	AC/AC	na	?	?	VFR	9R hs Twy S
415297 415296	Sep-98	Day	LAS	No	121	Turbojet	na	121	?	VFR	19L hs 25R
405615	Jun-98	Day	BUR	Yes	91	Cessna	na	121	2-eng Turbojet	VFR	8 hs 15

Appendix III.—ASRS/NAIMS LAHSO Events, 1994-1998 (continued)

Report Number	Mon/Yr	Time	Airport Id	Hold short Overrun? GAR? (Initiated by)	AC1 CFR	AC1 Type	Landing Distances 7110.196	AC2 CFR	AC2 Type	Basic Weather Conditions	Rnwy
406022	Jun-98	Day	ORD	No	121	B727	5680	?	?	VFR	14R hs 27L
Pilot Dev See 397321 397481	Mar-98	Day	BDL	Yes	121	SF-340	4410	91	Learjet	VFR	33 hs 24
Pilot dev	na	Day	LGB	Yes	91	?	na	?	?	VFR	12 hs 16L
402151	Apr-98	Day	ROC	No	121	SA-227	5510	121	Turbojet	VFR	28 hs 22
410159	Jul-98	Day	MIA	No	121	B767	5890	?	?	VFR	Mult. Rwys
404476 404474 404475	Jun-98	Day	ORD	Yes	121	B727	5680	121	2-eng Turbojet	VFR	27L hs 32L
413615	Sep-98	Day	MIA	AC1 GAR (AC1)	121	2-eng Turboprop	na	121	2-eng Turbojet	VFR	9R hs 12
413596	Jul-98	Day	DCA	AC2 GAR (AC2)	121	2-eng Turboprop	na	91	2-eng piston	VFR	36 hs 33
411438	Aug-98	Day	DFW	No	121	?	na	121	?	VFR	18R hs TwyB
412164	Aug-98	Day	DFW	No	121	?	na	121	?	VFR	Rwy31/35/36
413556	Sep-98	Day	DFW	No	121	?	na	?	?	VFR	Rwy35C hs TwyEJ
413441	Sep-98	Day	BOS	No	121	?	na	?	?	VFR	4L hs 33R
PSOTCVG98001	Feb-98	Dusk	CVG	Yes	121	B727	5680	121	B737	VMC	18R hs 9
399065	Feb-98	na	ORD	AC1 GAR (ATC)	121	?	na	121	?	MVFR	14R hs 9R
395137 395136 395502 394898 394977	Feb-98	Day	CVG	Yes	121	B727	5680	121	B737	VMC	18R hs 9
399065	Feb-98	Day	ORD	AC1 GAR (ATC)	121	?	na	121	?	MVFR-rain	
393496	Feb-98	Day	BDL	AC1 GAR (ATC)	121	?	na	121	?	MVFR	33 hs 6
392905*see note 5 below	Feb-98	na	LAS	No	121	?	na	121	?	na	19/25R/L
392838 392699	Jan-98	Day	CVG	No	121	B757-200	5850	121	B757-200	VMC	18R hs 9
390591 390590	Jan-98	Day	PHL	No	121	?	na	121	?	VMC	na
385990	Nov-97	Day	LAS	AC1 GAR (AC1)	121	A320	5780	121	B737-300	VMC	19? hs 25
385036	Nov-97	Day	DFW	AC2 RI	121	MD-80	6680	?	?	VMC	UNK

Appendix III.—ASRS/NAIMS LAHSO Events, 1994-1998 (continued)

Report Number	Mon/Yr	Time	Airport Id	Hold short Overrun? GAR? (Initiated by)	AC1 CFR	AC1 Type	Landing Distances 7110.196	AC2 CFR	AC2 Type	Basic Weather Conditions	Rnwy
383526	Oct-97	Day	ORD	No	121	B727	5680	121	MD-80	VMC	27L hs 32L
383107	Oct-97	Day	PWM	Yes	91	Bonanza 36	3490	121	B737	VMC	18 hs 11
382929 382930 382931	Oct-97	Day	LGA	Yes	121	MD-80	6680	121	MD-80	IMC	4 hs 31
382294	Oct-97	Day	ORD	Yes	121	SF-340	4410	121	?	VMC	14L hs 22R
382217	Oct-97	Night	Mdw	AC2 GAR (ATC)	91	?	na	121	?	VMC	22R hs 31C
381825	Oct-97	Night	BDL	AC2 RI	121	MD-80	6680	91	Beech Baron	VMC	24 hs 33
382346	Oct-97	Night	ORD	No	121	?	na	?	?	VMC	14 hs 9R
381038	Sep-97	Night	MIA	Op. Error? AC2 RI?	121	B727	5680	121	?	na	9R hs 12
379041 378875	Sep-97	Day	BOS	Yes	135	CE-402C	5160	121	B727-200	VMC	27 hs 22L
376959	Aug-97	Day	PNE	AC1 GAR (AC1)	91	?	na	91	?	VMC	24 hs 33
376854	Aug-97	na	ORD	No	121	MD-80	6680	121	?	na	27L hs 32L
376770	Aug-97	Day	PNE	AC1 GAR (AC1)	91	PA-28	3830	91	PA-31	VMC	24 hs 33
376593	Aug-97	Day	ORD	No	121	?	na	121	?	VMC	27L hs 32L
376718	Jul-97	Day	LAS	No	121	?	na	121	?	VMC	19L hs 7L
PSOTSDF970 03	Jul-97	Day	LOU	Yes	91	CE-340	4090	?	?	VMC	29 hs 19
PWPTLGB970 14	Jul-97	Day	LGB	Yes	91	CE-337-T337G	3760	?	?	VMC	12 hs 16L
376269	Jul-97	Day	ELM	No	121	2-eng Turboprop	na	121	EMB-100	VMC	28 hs 6
375210	Jul-97	Night	BUR	AC1 GAR (AC1)	91	1-eng recip	na	121	Commuter	VMC	8 hs 15
375307	Jul-97	Night	BUR	No	91	1-eng recip	na	121	B737	VMC	8 hs 15
PD PWPTBUR970 05 370383	May-97	Day	BUR	Yes	91	PA-32	3890	91	Baron 55	VMC	8 hs 15
PWPTBUR970 02	May-97	Day	BUR	Yes	91	BE-36-A36	3490	121	B737-100	VMC	8 hs 15/33
370381	May-97	Day	MIA	No	121	?	na	?	?	VMC	9R hs 12
PD PGLTORD970 02 369184	May-97	Day	ORD	Yes	121	B737-200	5580	121	Commercial fixed wing	VMC	27L hs 14R

Appendix III.—ASRS/NAIMS LAHSO Events, 1994-1998 (continued)

Report Number	Mon/Yr	Time	Airport Id	Hold short Overrun? GAR? (Initiated by)	AC1 CFR	AC1 Type	Landing Distances 7110.196	AC2 CFR	AC2 Type	Basic Weather Conditions	Rnwy
361150	Feb-97	Day	SBA	Yes	91	?	na	?	?	VMC	7 hs 15R
352865	Nov-96	Night	DCA	Yes	91	2 eng recip	na	?	?	VMC	3 hs 30
PCETSTL96003	Aug-96	Day	STL	Yes	135	MU-2B-2B	5930	121	B727	VMC	24 hs 30L
345500	Aug-96	Day	BOS	Yes	121	SF-340A	4410	?	?	VMC	4 hs 33R
PD PSOTTPA96002 343215	Aug-96	Day	TPA	Yes	121	Dash 8	3870	?	King Air	VMC	27 hs 18L
341414	Jul-96	na	ROA	AC1 GAR (AC1)	91	M-20J	4310	?	Turbojet	na	24 hs 33
PWPLGB96006	Jul-96	Day	LGB	AC1 Touch-go	91	CE-152	3010	91	BE-18-E18S	VMC	25R hs 30
338578	Jun-96	Day	DFW	Yes	?	S80	na	121	MD-80	na	18R hs txyB
337158	na	na	CLE	na	na	?	na	?	?	na	na
335251	May-96	Day	LGB	AC1 Touch-go	91	CE-152	3010	?	B737	VMC	25R hs 30
334926	May-96	Day	DFW	Yes	121	MD-80	6680	?	?	na	18R hs txyB
334010	Apr-96	Day	BUR	AC1 Touch-go	91	CE-150	2800	?	B737	VMC	8 hs 15
331450	Mar-96	Day	BUR	AC1 GAR (AC1)	91	1 eng- recip	na	?	?	VMC	8 hs 15
331028	Mar-96	Night	DCA	Yes	121	B737-300	5700	?	Citation	VMC	36 turn off N
325426	Jan-96	Day	ABQ	AC1 GAR (AC1)	121	B737-300	5700	?	Light aircraft	VMC	3 hs of 30
PD PSOTPIE95002 323338	Dec-95	Day	PIE	AC1 GAR (AC1)	91	PA-34-200	5350	?	?	VMC	17L hs of 4
321444	Nov-95	Dawn		Op Er? AC2 RI?	135	Jetstream	5310	?	?	VMC	36R hs 5/23
319372	Oct-95	Day	DTW	na	135	SA-227	5510	?	?	VMC	21L hs 27L
319247	Oct-95	Day	STL	Yes	135	Jetstream	5310	?	?	VMC	24 hs 30L
317818	Sep-95	Day	MSN	AC1 Touch-go	91	Skyhawk 172	3090	121	B727	VMC	? hs 18
299829	Mar-95	Night	ORD	Op Er? AC2 RI?	121	MD-80	6680	?	?	VMC	27L hs 14R?
295388	Feb-95	Day	DFW	Yes	121	MD-80	6680	?	?	VMC	18R hs B
PSOTFMY95001	Feb-95	Day	FMY	Yes	91	CE-152	3010	91	?	VMC	5 hs 13
293575	Jan-95	Day	YUM	Yes	91	?	na	?	?	VMC	17 hs 21R
292680	Dec-94	Day	SBA	Yes	91	?	na	?	?	VMC	7 hs 15
288268	Nov-94	Day	ORD	No	121	B727	5680	121	B737	IMC	14L hs 9L
285311	Oct-94	Day	PIE	AC1 Touch-go	91	CE-152	3010	?	C-130	VMC	22 hs 17L
279270	Jul-94	Day	PHL	Yes	121	Jetstream	5310	121	B737	VMC	17 hs 27R

Appendix III.—ASRS/NAIMS LAHSO Events, 1994-1998 (continued)

Report Number	Mon/Yr	Time	Airport Id	Hold short Overrun? GAR? (Initiated by)	AC1 CFR	AC1 Type	Landing Distances 7110.196	AC2 CFR	AC2 Type	Basic Weather Conditions	Rnwy
PGLTATW94001	Jun-94	Day	ATW	Yes	91	CE-172-N	3090	91	CE-182-P	VMC	3 hs 11
273660	Jun-94	Day	DFW	No	121	?	na	?	?	VMC	18R hs txy "31" (B?)
PGLTRST94003	May-97	Day	RST	AC1 Touch-go	91	CE-150-M	2800	91	na	VMC	13 hs 2
261666	Jan-94	Night	MIA	AC1 GAR (ATC)	121	B727	5680	121	B727	VMC	12 hs of 9R

Appendix IV.—NTSB Landing Overrun Accidents (14 CFR part 91), 1994-1998

Report Number	Local Date	Aircraft Make/Model	Aircraft RLD 7110.196	Seats	Wx Conds	Wind Dir	Wind Sp	Runway	ALD	Runway Cond.
CHI99LA002	10/4/98	CESSNA CE-336-XXX	3330	0	VMC	100	13	13	3993	na
NYC98LA153	7/26/98	CESSNA CE-337-G	3760	0	VMC	360	4	02	2605	na
CHI98LA246	7/9/98	CESSNA CE-182-L	3250	4	VMC	0	0	26	3501	na
NYC98LA134	6/24/98	CESSNA CE-172-M	3090	4	VMC	270	12	13	5100	na
CHI98LA100	3/4/98	CESSNA CE-650-650	5880	9	IMC	350	8	na	5202	na
FTW98LA124	2/3/98	PIPER PA-22-108	1880	2	VMC	30	15	na	4800	na
IAD98LA020	1/4/98	CESSNA CE-172-M	3090	0	VMC	0	0	na	2625	na
CHI98LA077	1/2/98	PIPER PA-34-220T	5350	4	VMC	220	21	na	3000	na
ATL98LA011	11/21/97	BEECH BE-60-B60	6180	6	IMC	70	6	27	5522	Wet
ATL97LA130	9/1/97	BEECH BE-95-A55	4710	6	VMC	40	4	na	3898	Wet
ATL97LA109	7/20/97	CESSNA CE-172-M	3090	4	VMC	240	3	na	4700	na
NYC97LA130	6/28/97	PIPER PA-28R-200	3830	4	VMC	250	3	na	2550	na
CHI97LA189	6/28/97	CESSNA CE-172-P	3090	4	VMC	180	5	na	3040	na
FTW97LA197	5/22/97	CESSNA CE-172-RG	3090	4	VMC	350	4	na	2600	Wet
NYC97LA075	4/14/97	PIPER PA-28-161	3830	4	VMC	40	4	na	2580	na
LAX97LA145	4/4/97	BEECH BE-60-B60	6180	6	VMC	240	16	08	5850	na

Appendix IV.—NTSB Landing Overrun Accidents (14 CFR part 91), 1994-1998 (continued)

Report Number	Local Date	Aircraft Make/Model	Aircraft RLD 7110.196	Seats	Wx Conds	Wind Dir	Wind Sp	Runway	ALD	Runway Cond.
SEA97LA066	2/25/97	CESSNA CE-152-152	3010	2	VMC	210	6	na	na	na
CHI97LA057	1/21/97	BEECH BE-300-300	5010	11	IMC	160	10	35	6500	na
CHI97LA028	11/16/96	PIPER PA-32R-301T	3890	6	VMC	0	16	27	3658	na
MIA97LA019	11/9/96	BEECH BE-36-A36	3490	6	VMC	280	13	na	2725	na
NYC97LA014	11/7/96	CESSNA CE-340-A	4090	4	IMC	150	4	15	3210	Wet
IAD97LA007	10/13/96	MOONEY MOONEY-20-J	na	4	VMC	40	3	8	2700	na
IAD96LA146	9/15/96	PIPER PA-28-235	3830	4	VMC	290	6	na	5100	na
IAD96LA143	9/2/96	CESSNA CE-210-T210N	3510	6	VMC	20	4	na	2360	na
FTW96LA358	8/24/96	PIPER PA-28-235	3830	4	VMC	360	4	na	2580	na
LAX96LA296	8/4/96	CESSNA CE-421-C	4850	8	VMC	0	3	na	3240	na
ATL96LA109	7/20/96	BEECH BE-58-P	5180	6	VMC	120	10	12	4600	na
IAD96LA110	7/10/96	MOONEY-20-20	na	4	VMC	290	7	na	na	na
FTW96LA301	7/6/96		na	2	VMC	210	8	18	3000	Wet
LAX96LA256	7/1/96	MOONEY-20-E	na	4	VMC	0	0	17	2620	na
NYC96LA124	6/13/96	CESSNA CE-172-K	3090	4	VMC	180	5	na	2999	na
LAX96LA211	5/24/96	BLANCA BL-17-30A	1920	4	VMC	225	10	18	2160	Wet
IAD96LA062	4/14/96	CESSNA CE-182-P	3250	4	VMC	70	9	36	na	na

Appendix IV.—NTSB Landing Overrun Accidents (14 CFR part 91), 1994-1998 (continued)

Report Number	Local Date	Aircraft Make/Model	Aircraft RLD 7110.196	Seats	Wx Conds	Wind Dir	Wind Sp	Runway	ALD	Runway Cond.
LAX96LA182	4/11/96	CESSNA CE-402-C	3950	2	VMC	260	33	na	5323	na
FTW96LA165	4/7/96	PIPER PA-24-250	2620	4	VMC	0	0	na	2480	na
ATL96LA077	4/6/96	CESSNA CE-210-210	3510	6	VMC	240	8	na	2400	na
NYC96LA065	2/23/96	PIPER PA-46-350P	3990	6	IMC	0	0	na	2733	na
LAX96LA079	12/26/95	CESSNA CE-182-Q	3250	4	VMC	360	15	18	2160	na
LAX96LA020	10/24/95	PITTS	na	1	VMC	0	0	na	2600	na
BFO96LA002	10/4/95	BEECH BE-95-B55B	4710	6	VMC	140	4	na	2505	Wet
NYC95LA227	9/28/95	CESSNA CE-172-RG	3090	4	VMC	100	4	23	2534	na
CHI95LA317	9/11/95	PIPER PA-28-181	3830	4	VMC	140	12	na	2100	na
ATL95LA157	8/12/95	CESSNA CE-172-H	3090	4	VMC	190	10	na	3300	na
NYC95LA187	8/12/95	PIPER PA-28-180	3830	4	VMC	360	10	na	2700	Wet
CHI95LA251	7/29/95	PITTS PITTS-S2-B	na	2	VMC	130	9	na	3495	na
CHI95LA240	7/26/95	CESSNA CE-500-S550	4680	10	VMC	180	3	na	na	na
LAX95LA266	7/23/95	CESSNA CE-172-N	3090	4	VMC	240	8	na	4600	na
LAX95LA227	6/28/95	CESSNA CE-150-M	2800	2	VMC	320	11	12	2985	na
LAX95LA230	6/24/95	PIPER PA-34-200	5350	7	VMC	0	0	na	3240	na
LAX95LA220	6/21/95	CESSNA CE-310-310	4000	4	VMC	40	3	na	5000	na

Appendix IV.—NTSB Landing Overrun Accidents (14 CFR part 91), 1994-1998 (continued)

Report Number	Local Date	Aircraft Make/Model	Aircraft RLD 7110.196	Seats	Wx Conds	Wind Dir	Wind Sp	Runway	ALD	Runway Cond.
CHI95LA179	6/13/95	CESSNA CE-210-T210M	3510	6	VMC	300	5	na	2900	na
LAX95LA205	6/10/95	CESSNA CE-210-T210M	3510	6	VMC	60	2	na	2820	na
FTW95LA220	5/28/95	PIPER PA-28-140	3830	4	VMC	210	10	na	4183	na
FTW95TA218	5/20/95	CESSNA CE-172-R172k	3090	4	VMC	320	9	na	4010	na
NYC95LA113	5/19/95	BEECH BE-23-A2324	3480	4	VMC	340	17	na	2830	na
BFO95FA050	5/12/95	CESSNA CE-172-F	3090	2	VMC	340	6	na	2785	na
CHI95LA129	4/19/95	BEECH BE-19-B	3830	4	VMC	50	10	na	2480	na
BFO95LA040	4/1/95	ARONCA AR-7-DC	na	2	VMC	330	10	na	3457	na
MIA95LA074	2/15/95	CESSNA CE-525-525	na	7	VMC	220	9	na	4000	na
CHI95LA083	2/5/95	PIPER PA-28-181	3830	4	VMC	330	14	na	2812	na
CHI95LA070	1/20/95	CESSNA CE-172-K	3090	4	VMC	330	15	9	na	Icy Rwy
NYC95LA044	12/20/94	PIPER PA-28-181	3830	4	VMC	0	0	na	2579	na
BFO94LA131	8/10/94	PIPER PA-28-236	3830	4	VMC	290	10	na	2030	na
CHI94LA268	8/7/94	PIPER PA-28-181	3830	4	VMC	180	5	na	2577	na
NYC94LA150	8/5/94	BEECH BE-58-P	5180	6	VMC	30	10	22	3000	na
CHI94LA252	7/31/94	CESSNA CE-210-L	3510	4	VMC	180	7	36	2510	na
CHI94LA228	7/9/94	BEECH BE-58-58	5180	6	VMC	290	11	na	4001	Wet

Appendix IV.—NTSB Landing Overrun Accidents (14 CFR part 91), 1994-1998 (continued)

Report Number	Local Date	Aircraft Make/Model	Aircraft RLD 7110.196	Seats	Wx Conds	Wind Dir	Wind Sp	Runway	ALD	Runway Cond.
LAX94LA228	5/30/94	PIPER PA-28-151	3830	4	VMC	0	0	na	2480	na
CHI94LA171	5/24/94	CESSNA CE-172-N	3090	4	VMC	60	3	na	3501	na
SEA94LA102	4/16/94	CESSNA CE-172-L	3090	4	VMC	100	10	na	2412	na
ATL94LA066	3/19/94	BOEING B-75-A75N1	na	2	VMC	250	10	2	3744	na
NYC94LA063	3/17/94	CESSNA CE-172-RG	3090	4	VMC	310	7	9	3721	na
NYC94LA060	3/10/94	CESSNA CE-172-K	3090	4	VMC	290	7	na	5000	na
LAX94LA127	2/18/94	PIPER PA-23-250	2260	4	VMC	240	16	na	5000	na
ATL94LA044	1/26/94	CESSNA CE-310-310	4000	4	IMC	80	4	na	5000	Wet

Appendix V.—NTSB Landing Overrun Accidents (14 CFR part 121), 1994-1998

	Report Number	Local Date	Time	Airport Id	Aircraft Make/Model	Aircraft RLD 7110.196	Seats	Wx Conds	Wind Dir	Wind Sp	Rnwy	ALD	Rnwy Cond
1	NYC98SA077	3/14/98	1310 EST	PWM	DOUG MD-88	6680	0	IMC	160	13	11	6800	snow/wet
2	FTW97IA365	9/25/97	0939 CDT	MSY	DOUG DC-9-83	6530	0	VMC	300	7	01	7000	wet
3	ATL96IA056	2/28/96	1645 EST	SAV	DOUG DC-9-32	6530	120	VMC	260	8	36	7003	na
4	FTW96IA124	2/20/96	2158 MST	RIL	AVRO-146-RJ70A	7850	73	VMC	098	6	26	7000	slush/wet
5	IAD96IA044	2/20/96	1512 EST	DCA	BOEING B737-130	5580	95	IMC	40	7	36	6869	wet
6	ATL95IA043	1/19/95	0940 EST	ATL	BOEING B737-247	5580	130	IMC	120	13	na	na	wet
7	DCA94MA033	2/1/94	1759 EST	LA30	SAAB SF340B	4410	30	VMC	220	4	na	5000	na

Appendix VI.—NTSB Landing Overrun Accidents (14 CFR part 135), 1994-1998

	Report Number	Local Date	Time	Airport Id	Aircraft Make/Model	Aircraft RLD 7110.196	Seats	Wx conds	Wind Dir	Wind Sp	Rnwy	ALD	Rwy Cond
1	CHI97LA049	1/1/97	230 CST	MKC	LEAR LR-35-35	7350	2	IMC	200	10	3	5052	Wet
2	LAX96LA289	7/24/96	815 PDT	O19	PIPER PA-31-350	4800	2	VMC	0	0		2200	na
3	FTW96LA123	2/21/96	255 CST	RBD	BEECH BE-95-C55	4710	6	VMC	170	15	35	3801	na
4	SEA96LA056	2/16/96	1045 PST	8S2	CESSNA CE-172-P	3090	4	VMC	0	0		1800	na
5	ATL95LA068	3/20/95	1345 CST	M15	PIPER PA-60-601P	na	2	VMC	230	15	18	3600	Wet
6	ATL95LA028	12/14/94	918 EST	HKY	CESSNA CE-402-B	3950	2	IMC	0	0	24	6400	na
7	LAX94LA302	7/29/94	1620 EST	4PH	CESSNA CE-421-C	4850	5	VMC	240	3	22	na	na
8	DCA94MA053	4/27/94	3/5/06	BDR	PIPER PA-31-350	4800	10	VMC	250	5	6	4677	na
9	IAD97IA045	1/25/97	1400 EST	PVC	CESSNA CE-402-C	5160	10	IMC	220	15	7	3500	na

Appendix VII: Comments from Risk Assessment Team Participants

SOUTHWEST

SOUTHWEST AIRLINES CO.

Captain Greg Crum
Director Flight Operations/Chief Pilot

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July 26, 1999

Mr. Gregory Won
Federal Aviation Administration
Office of System Safety, ASY-300
800 Independence Avenue, SW
Washington, DC 20591

Dear Mr. Won:

Southwest Airlines Comments and Response to the Draft Land and Hold Short Operations Safety Risk Assessment

Comments:

Page VI Glossary- SWA, Southwest Airlines should be added since it participated in the risk analysis.

Page 8 next to last paragraph "One participant suggested adopting a regulation to establish minimum experience requirements (e.g., flight hours in type) for LAHSO." This mischaracterizes what the participant, Southwest Airlines, suggested which was to incorporate LAHSO into FAR 121.438. This regulation stops the second in command with less than 100 hour in type unless with a qualified check pilot from landing the airplane under various situations including at special airports, and with a crosswind component in excess of 15 knots. With as many safety concerns as exist for LAHSO surely it warrants inclusion in this regulation.

Page 88 Risks Associated with Rejected Landings. C. Hazards that could degrade existing controls. The 2000 ft criteria for departing GA aircraft in determining the need for a rejected landing procedure is inadequate in almost all cases. "One participant noted that at least one set of instructions may require a VFR aircraft to fly into instrument meteorological conditions." This misstates what the participant, Southwest Airlines, noted. The "set of instructions" is the published rejected landing procedure itself. It is not just a VFR aircraft but an IFR aircraft that has accepted a visual approach clearance. The visual approach has no missed approach segment and therefore the aircraft must remain in VMC in the event of a rejected landing, possibly in direct conflict with the published rejected landing procedure. Considering the number of air carrier aircraft utilizing visual approaches on IFR flight plans this represents a larger set than just VFR aircraft.

Page. 88 D. Suggested Risk Reduction Strategies. "Although the team did rate risks associated with rejected landings, the specifications of current controls are still being developed and so these ratings have limited value." Land and hold short operations are currently being conducted with the controls that were in place at the time of the teams rating of risk. Why does this become the category of the report not to have the teams rating published? This is particularly troubling considering the trouble and length of time the team spent in discussing the various issues related to the rejected landing situation. "Work between these groups to establish adequate procedures is continuing at the time of this writing." Neither Southwest Airlines nor Southwest Airlines Pilot Association has been made aware of any continuing work in this area.

Response:

Southwest Airlines strongly agrees with the recommended risk reduction strategies contained in the main body and appendix II of the draft report of July 9th, 1999. Further, Southwest Airlines is currently employing it's own safety risk management by not participating either actively or passively in Land and Hold Short Operations. We view the Office of System Safety risk analysis resulting in 29 suggested risk reduction strategies as sufficient evidence that the LAHSO program as it is currently conceived is inadequate in design with respect to safety and therefore premature in it's implementation.

Sincerely,

Greg Crum

Greg Crum

xc: Gregory.Won@faa.gov

AIR LINE PILOTS ASSOCIATION, INTERNATIONAL
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August 4, 1999

Mr. Gregory Won
Federal Aviation Administration
Office of System Safety, ASY-300
800 Independence Avenue, S.W.
Washington, DC 20591

Dear Mr. Won:

We have reviewed the July 1999 Draft LAHSO Risk Assessment. We think that it accurately identifies the risks associated with LAHSO and outlines sound management strategies for risk reduction. As we have previously stated, we believe that LAHSO is a viable capacity enhancement tool. Application of these risk reduction strategies will improve the safety of the operations.

We remain committed to participate in all the work on risk mitigation measures and are currently involved in the LAHSO Review Team headed by Howard Swancy, as well as the LAHSO light evaluation at the FAA Technical Center next week. The results of these groups should be integrated into the risk assessment and LAHSO procedures should be appropriately modified without delay. We are concerned about the prudence of continuing LAHSO with all the open issues identified in the risk assessment.

We appreciated the opportunity to review the document and look forward to continuing this work.

Sincerely,

Captain Paul McCarthy
Executive Air Safety Chairman

PM:dy

Comments from the Aircraft Owners and Pilots Association

1. ***Summary of Findings*** *(page three, paragraph three)*
The suggestion to limit Land and Hold Short Operations (LAHSO) to select locations where there is a demonstrated economic/capacity need defeats the purpose of the original intent of the LAHSO program. LAHSO under its previous name, Simultaneous Operations to Intersecting Runways (SOIR) has been conducted for many years. Perhaps the FAA should consider location specific authorizations for LAHSO which utilize hold short points not affiliated with a runway intersection.

2. ***Baseline Estimates of LAHSO Risks*** *(page four, bullet one)*
It is unclear why go-arounds are used as part of the LAHSO statistics in this paragraph. An overrun is a violation of the LAHSO. A go-around may not necessarily reflect a violation of the operation. Further, the go-around maneuver could be conducted during LAHSO for many reasons and it shouldn't be looked at as a poor operational practice. Pilots are taught that the go-around doesn't reflect lack of piloting skill or ability. Rather, pilots are taught that the decision to go-around increases safety and demonstrates the pilot's ability to exercise good judgement and aeronautical knowledge.

   Although a go-around may create potential for aircraft conflict during LAHSO, a go-around during other non-LAHSO operations can also create similar safety issues. Thus, all things being equal, the go-around should not be considered in the historical rate for LAHSO safety analysis.

3. ***Historical Background*** *(page 19, paragraph three)*
Change the sentence to indicate that the February 9, 1999 agreement is with associations representing airline pilots.

4. ***Suggested Risk Reduction Strategies*** (page 63)

   Anti-stuck microphone and anti-block radio technology.

   By the placement of this suggested improvement separate from the long-term controls, it is inferred that this potential improvement could be implemented quickly. Currently, there aren't any general aviation aircraft operating in the national airspace system with this technology. It is a severe understatement to believe that this is a near term solution to some of the communications issues revealed during this risk assessment.

5. ***Risks associated with piloting technique*** *(page 72)*
B. Landing Technique

   Controls relating to the pilot, third bullet

   The assessment lists the non-air carrier LAHSO mix as an existing control. Although it exists in the current NOTICE, the FAA has assured AOPA that it will not be part of the Order soon to be released. This control should not be listed since it is temporary in nature and will not be part of the permanent order.

Comments from the Regional Airline Association

In general RAA considers that the current LASHO provides an acceptable level of risk; however the proposed "improved" lighting should be delayed and the determination of ALD's for the regional/ commuter airplanes should be revised.

Rejected Runway Criteria: The rejected landing criteria unfortunately this criteria fits only a few airport intersections so if LASHO is to be conducted at most of the airports where it is presently conducted, additional rejected runway procedures need to be developed. This remains to be accomplished.

Communications: RAA consider that crew and air traffic training should address risk issues associated with communications.

Crew Performance- Landing Technique: The new ALD criteria, AFM distance (times 1.67) plus 1,000 feet has placed several regional airplane types (e.g. B1900, Emb-120, Jetstream 4101) into totally unrealistic ALD groupings. Adding a 1,000 foot "penalty" to establish ALD provides a disproportionate penalty for smaller airplane types to qualify for LASHO. An ALD based simply on AFM criteria is overly conservative since it does not provide credit for reverse prop and thrust reverser deployment; Previous LASHO criteria provided credit for thrust reverser deployment on wet runways such that the wet runway ALD was less than the ALD was for dry runways! The commuter category airplanes without anti-skid have a significantly greater AFM ALD; While this may be valid in determining wet runway stopping distances, it becomes less valid if only dry runway LASHO is provided. The end result of having greater ALD's for the regional/commuter airplanes is that they will no longer qualify for LASHO on many "regional/commuter" runways; whether this results in more vectoring of the regional/commuter airplane types to fit into the larger airplane traffic flow onto the larger runways, remains to be seen.

Tailwind/Crosswind, Gusts, Windshear: Current policy provides an acceptable level of risk.

2 Bar Lighting System: The test that was conducted to validate the "improved" lighting configuration was incomplete. From the 777 cockpit vantage point, the pulsing lights at the alert point may have provided a beneficial visual cue to prepare the flight crew of the impending hold point. However the visual observation of the impending runway from a 777 cockpit is significantly different than from a regional/commuter airplane as it is rolling down the runway and further testing should be provided to determine whether the pulsing lights at the alert point will provide any value at all to the crew of a regional/commuter airplanes. In addition, the reluctance of one of the pilots who conducted the test to move the airplane beyond the pulsing white light (alert point) without further clarification indicates a unacceptable risk leading to confusion of the crew. Since Canada and Europe have no intention of installing two banks of LASHO lights, the opportunity for further confusion on what the lights actually mean, remains high. Lastly the placement of alert lights 1,000 feet prior to the hold point simply doesn't "fit" for many runways. Sometimes the alert point is at or near the runway intersection and the pulsing lights could create confusion for the other runway traffic. Clearly more studies to validate the safety of installing the "improved" lighting configuration should be accomplished.

LASHO-Night: . The level of risk for night operations is acceptable when weather conditions are favorable.

LASHO- Wet: The use of thrust reverser and reverse prop should be allowed in the determination of wet runway LASHO. LASHO wet should be re-instated.

Aircraft Systems: The level of risk is acceptable. MMEL dispatch procedures adequately address the safety issues.

Contaminated Runway: This should be the responsibility of the airport tower in determining whether LASHO should/should not be conducted because of contamination. Pilots are under a continuing responsibility to report to the tower regarding changed conditions.

Thank you, Dave Lotterer, RAA